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THE EVOLUTION OF THE STARRY HEAVENS.*

T. J. J. SEE

We are assembled to consider the great Law of Nature which governs the Evolution of Worlds, and to celebrate the founding of a New Science of the Starry Heavens. Prior to the establishment of the Science of Cosmogony, from researches made here in California during the past few years, the most recent astronomical science developed by a modern investigator was *Astrophysics*, which was founded by the late Sir William Huggins half a century ago. From this circumstance it is not without inspiration to recall the lively interest taken by this illustrious pioneer in the development of the New Science of *Cosmogony*. For just as in early manhood he foresaw with prophetic vision the great possibilities of *Astrophysics*, so also in the last years of a long life consecrated to the advancement of truth, this venerable philosopher was one of the first to welcome the founding of a New Science of Cosmical Evolution. We may pause to recall the early words of Sir William Huggins, which were the more appreciated because they were uttered before the New Science had become established in the scientific world.

Writing from London, under date of August 11, 1908, he says:—"I hasten to thank you for your letter giving me early information of your bold and startling new theory of spiral nebulae. It takes one's breath away to endeavor to realize the going round of these long drawn out wisps, I suppose, billions of billions of miles long! At the first blush one would hardly expect them to make headway in any resisting medium. But your theory gets out of the astonishing difficulty of how they exist, if *at rest*, in any state approaching equilibrium. If,

* Address to the California Academy of Sciences, delivered August 7, 1911

as you say it does, the thing works out, we seem to have reached something like certainty in a subject which hitherto has been in more senses than one a nebulous one. I am greatly interested and shall look forward to the fuller working out of your ideas. Laplace's theory is no doubt vulnerable."

In a note of June 6, 1909, Sir William added: "It is indeed an exciting time when one's old notions are disappearing under the light of new knowledge. One almost regrets the time when one could sleep comfortably in Laplace's bosom."

On September 12, 1909, Sir William wrote: "I have received, and desire now to thank you for, separate copies of your important papers on the Capture of Satellites, and of the moon, which appeared in the *Astronomische Nachrichten*. From the point of *sentiment* it is, perhaps, disappointing to learn that our old moon is not an earth-son, but some gypsy body, and that all the planets and satellites of our system are not children and grand-children of the sun, but 'undesirable aliens' from nobody knows where! But fact and truth come before sentiment, and your views claim the earnest consideration of all astronomers."

Another celebrated philosopher who early welcomed these new advances and therefore is not to be forgotten by us tonight, is the lamented Schiaparelli, the most illustrious Italian astronomer since the days of Galileo. He heartily rejoiced to be able to recognize in the recent discoveries the aurora which heralds the coming day of a new science of Cosmogony, and pointed out that heretofore astronomers had been mainly occupied with ascertaining the present state of the heavens.

On the occasion of this anniversary, three years after the first private announcements were made to Sir William Huggins, ex-President of the Royal Society, and acknowledged by him in the letters above quoted, we find the new Science of Cosmogony already widely recognized by the most eminent astronomers and geometers. To all who have extended this generous welcome to new truth struggling for a foothold in the world, it is needless to say that we return most humble and hearty thanks, but to none more appropriately than the illustrious Poincaré, the foremost natural philosopher and geometer of our age.

Writing to me from Paris under date of July 6, 1911, this incomparable mathematician says: "I have made use of your book (*Researches*, Vol. II) in my course this year, although I

PLATE XVII.

POINCARÉ,

THE EMINENT FRENCH MATHEMATICIAN AND NATURAL PHILOSOPHER,
AND ONE OF THE GREATEST OF MODERN ASTRONOMERS.

had not expected to do so, since I did not receive the volume till near the close of the last lesson; I then insisted, with profit, on the capture of planets by a resisting medium."

"My course is being published and I shall send it to you as soon as it appears, that is to say, in the month of November. You will see there the remarks and the difficulties which your theories have suggested to me.

Your very devoted Colleague,

POINCARÉ."

Among the other investigators who have joined in this notable advance, special mention should be made of the work of our eminent colleague Professor E. W. Brown, of Yale University, for an important extension of our knowledge of the Capture of Satellites (*Monthly Notices of Royal Astronomical Society*, March, 1911); and of the recent researches of Professor Elis Strömgren, of the Royal Observatory of Copenhagen, demonstrating the elliptical character of the orbits of all comets, thus showing that they are attached to the Solar System, and do not move in parabolic or hyperbolic orbits, as was long believed. This work of Strömgren has removed the last important difficulty in establishing the Science of Cosmogony. Indeed his researches on comets seem likely to constitute the most notable advance in our theory of these mysterious objects since the days of Tycho, Kepler and Newton.

I. CIRCUMSTANCES ATTENDING THE DEVELOPMENT OF THE NEW SCIENCE OF COSMOGONY.

From these considerations it is evident that we have recently witnessed the development of a new science of the starry heavens. As will be seen hereafter it throws a clear light upon the astronomy of the invisible,* and illuminates the remotest regions of space almost as brightly as those well-lighted portions in the neighborhood of the sun, where the planets move. In fact it has been justly remarked that our new science lights up the firmament not unlike a new star which suddenly appears in the sky; and its development seems to have been almost as unexpected. We are still dazzled by the splendor of the light which has been suddenly thrown on the invisible processes of creation. For the processes of Cosmical Evolution are so

* Systems of planets, asteroids, satellites and comets are wholly invisible at the distance of the fixed stars, yet they are now proved to exist about all these suns.

slow that they extend over vast ages, and in general cannot be directly *observed*, but must be *inferred*, from the order now found to pervade the sidereal universe.

Like astronomy itself, Cosmogony in a primitive way dates back to the age of the Greeks, having been allegorically treated by the poets and afterwards more adequately developed by such natural philosophers as Anaximander, Democritus and Anaxagoras; so that it is at once the oldest and the newest of the sciences. But it is only within the last twelve years that we have secured the necessary data of observation, on the nebulae, chiefly by Keeler and Perrine at Lick Observatory, and introduced rigorous mathematical criteria which give us the permanent basis of a true physical science. Accordingly whilst *Astronomy Proper* was placed on a secure foundation by the researches of such ancient geometers as Apollonius, Aristarchus and Archimedes, combined with the observational data of Timocharis, Hipparchus and Ptolemy, *Cosmogony* proved to be much more difficult to reduce to a satisfactory basis of observation and demonstration, and has become a science only since the beginning of the twentieth century.

It is justly remarked that a high order of knowledge of the stars and their systems and of the chaotic nebulae from which they arose was necessary before it was possible to attempt to develop a real science of world formation. Thus for upwards of 2000 years Cosmogony remained little more than an unsatisfactory collection of opinions; and even quite recently one eminent mathematician, who still adheres to the old way of thinking, has likened Cosmogony to Astrology, holding that the secrets of the origin of the Universe are forever beyond the powers of the human mind. These views, of course, are erroneous, and yet they give us some idea of the difficulties which have been overcome. It is a remarkable fact that our philosophical difficulties have consisted chiefly in false premises. These obstacles ought to have been foreseen and avoided, but there were peculiar circumstances which long deceived the most eminent mathematicians—including Laplace, Sir John Herschel, Lord Kelvin, Newcomb, Darwin, Tisserand, and Poincaré. We shall presently trace the development of the new Science of Cosmogony with enough detail to render the results intelligible, but we shall first consider the conditions requisite for the creation of a new Mathematical Science.

II. Conditions Requisite for the Founding of Exact Sciences.

As already pointed out, Cosmogony deals with the laws of the formation of the heavenly bodies; and the perfection of this new Physical Science must be regarded as the ultimate object of all astronomical research. However special our individual investigations may be, this is the one ultimate purpose which they may be supposed to serve. And until the laws of Cosmical Evolution can be at least roughly outlined all our astronomical efforts are as aimless for the discovery of the highest laws of nature as are the unguided steps of the blind leading the blind. No wonder that astronomers should value researches which will give us light on the laws of Cosmogony, heretofore veiled in the darkness of perpetual night. Such discoveries are like the heavenly manna for feeding the famished wanderer in the wilderness searching for the way to the promised land.

The pioneer in Science must always be both an explorer and an apostle. His path must necessarily be lonely and desolate, and beset by the most unexpected difficulties. It takes as courageous a soul to lead the way to new fields of knowledge as it does to blaze the way to a new civilization, such as the pioneers of our country founded in early days of this Republic. No wonder that those who came after the hard and rough work is done have always said "Blessed be the Memory of the Pioneers."

Let me justify this opinion of the difficulties of the highest mathematical science by the great authority of Plato, who has been justly regarded as the most luminous intellect of the ancient times. This greatest of the Greek sages declared that "an astronomer must be the wisest of men; his mind must be duly disciplined in youth; especially is mathematical study necessary; both an acquaintance with the doctrine of number, and also with that other branch of mathematics, which, closely connected as it is with the heavens, we very absurdly call *Geometry*, the measurement of the earth."(Epinomis, p. 988-900)

With Plato's estimate of the intellectual qualification of an astronomer before us, will anyone believe that a modern astronomer can have any real standing who is not a mathematician? If sound mathematical knowledge was necessary in the simple age of the Greeks, how much more necessary is it now, with problems vastly more complex and difficult than any

treated by the ancients? Obviously Astronomy is not possible without the exact methods of Mathematics, and this criterion is a safe one in fixing the standard of any Physical Science.

Not only must the astronomer be the wisest and intellectually the most penetrating of men, but in order to be a discoverer of the first order, he must be just in his habits of mind and wholly devoted to truth. In a celebrated saying preserved by Plutarch, (Quest. Conv., VIII,2) Plato declares that "the Deity always geometrizes" — *ὁ θέος αεί γεωμέτρει.** Since the astronomer therefore labors to discover the laws and processes established by the Deity from the foundation of the world, it is evident that this highest order of truth can be perceived only by those who are philosophically equable and altogether devoted to the search for the correct principles of science. The kingdom of ideas thus disclosed to the faithful philosopher passeth not away, but endureth from generation to generation, as ageless as the heavens!

III. Six Principal Epochs in the Science of the Heavens.

The importance of any development in Astronomical Science depends on the light it throws on the physical causes which underlie the phenomena of the Universe. Laplace justly says that Tycho Brahé, great observer though he was, had little intuition into causes, and History therefore does not rate Tycho in the same class with Kepler and Newton, who established the laws of the heavenly motions. By this criterion that the importance of a discovery depends on the light it throws on causes, we find that there have been six principal epochs in the History of Astronomy.

1. *The Epoch of the Greeks*, who studied the apparent motions of the planets, and deduced the fact that their paths are nearly exact circles; whence it was supposed that the orbits are circular, because the Deity had chosen this perfect geometrical figure for the paths of the heavenly bodies. This comprised the work of Plato and Aristotle, Eudoxus and Apollonius, Aristarchus and Archimedes, Hipparchus and Ptolemy.

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* The plate with this inscription, used as a frontispiece to this address, is really a book-plate kindly presented to me by California friends who take great interest in the recent discoveries in Cosmogony. The portrait is one of Plato, and, above, Kaulbach's painting of Homer and the Greeks,—representing the atmosphere in which Plato lived. The other figures represent the spiral nebula 74 Piscium and the finished solar system.

HIPPARCHUS

THE FOUNDER OF THE SCIENCE OF ASTRONOMY, AND THE MOST FAMOUS OF THE GREEK ASTRONOMERS.

[Explanation:—This genuine portrait of Hipparchus is based on an antique Cameo found by Admiral Smyth, the British Amateur Astronomer, during a cruise in the Mediterranean about the year 1813, most likely at Athens or Alexandria. An outline of it is given in Chamber's Astronomy, Vol. III. As here presented it has been carefully enlarged by Mr. A. E. Axlund, and the deficient parts filled out by Professor See, who added the base, with inscription from Potemy, who praises Hipparchus as a "labor-loving and truth loving man."]

2. *The Epoch of Copernicus*, who established the heliocentric theory of the world in 1543, and showed that Aristarchus of Samos was right in holding that the stars are at a nearly infinite distance from our sun, and thus should suffer no sensible displacement from the annual motion of the earth in its orbit.

3. *The Epoch of Kepler and Galileo*, the one the discoverer of the laws of the planetary motions, the other the inventor of the telescope and discoverer of the laws of falling bodies, by which terrestrial and celestial motions could be compared and critically investigated. These great discoveries paved the way for the science of the heavenly motions as developed by Newton.

4. *The Epoch of Newton*, who established the law of universal gravitation and reduced all observed phenomena to approximate conformity with this great law of nature.

5. *The Epoch of Lagrange and Laplace and Herschel.* The first two great geometers verified and extended the Newtonian law, and also established the essential stability of the Solar System; while Herschel explored the sidereal universe and thus afforded an observational basis for an imperfect beginning of Cosmogony in the old Nebular Hypothesis. The problem of the stability of the Solar System now appears in a new light, for we find that only planets with stable motions have survived, while a vast number of small bodies moving in unstable orbits have been swallowed up and destroyed to lay the foundations of the larger masses of our system. The orbits which survive are thus free from mutual entanglement, and arranged as if to endure almost forever.

6. *The Epoch now growing out of the Development of a Science of Cosmogony*, which is made possible partly by the perfection of astronomical photography and partly by the solution of the restricted problem of three bodies. This leads at once to a great increase in our knowledge of the nebulae and of their mode of development into Cosmical Systems, under laws which are demonstrated to be consistent with the established principles of the mechanics of the heavens.

The present epoch is the one towards which all the previous epochs have pointed, and for which the great discoveries of the past have laid the foundations. The epoch of Cosmogony has been especially advanced by the researches and discoveries of American astronomers, beginning with the photographic work of Keeler in 1899; so that this Science of the Centuries seems

likely to be peculiarly an American Science. It has been considerably advanced also by eminent European investigators, among whom Darwin, Poincaré, Arrhenius and Strömgren seem to have taken the leading part.

In order to bring out the most significant facts, we shall consider in succession a number of topics. It is not necessary to dwell on Laplace's old nebular hypothesis, because it is now universally abandoned by astronomers, but we may recall very briefly the line of argument developed in Babinet's criterion, by which the detachment theory was finally overthrown, and the new Theory of Capture, or of addition from without, was introduced to take its place.

Such a complete transformation of this great subject necessarily involves new causes heretofore quite overlooked; among which we should mention the Resisting Medium and the operation of Repulsive Forces in Nature. The resisting medium has exercised vast influence in building up central masses and reducing the size and eccentricity of orbits, producing incidentally the capture of satellites; while the Repulsive Forces have operated to disperse matter in the form of fine dust from the stars, to produce nebulae, which finally condense into all manner of planetary and stellar systems. Even the comets as well as variable and temporary stars, thus find a simple explanation in accordance with the general laws of the heavens.

IV. Babinet's Criterion Shows that Laplace's Cosmogony Rests on a False Premise.

In the *Comptes Rendus* of the Paris Academy of Sciences for March 18, 1861, Babinet introduced an important Criterion showing that Laplace's Cosmogony was erroneous, by proving from the mechanical principle of the conservation of areas, that when the sun is expanded to fill the orbits of the planets, as imagined by Laplace, the rotation is much too slow to develop a centrifugal force adequate to detach the planets. The following table gives the principal data from Babinet's Criterion as now applied to the planets and satellites of the Solar system:

I. Table Showing the Application of Babinet's Criterion to the Planets and Satellites when the Sun and Planets are Expanded to fill the Orbits of the Bodies Revolving About Them.

Solar System.

Planet.	R_o The Sun's Observed Time of Rotation.	P_o Observed Period of Planet.	R_c Time of Sun's Rotation Calculated by Babinet's Criterion.
Mercury	25.3 days =0.069267 yrs.	0.24085 yrs.	479 yrs.
Venus		0.61237 "	1673 "
The earth		1.00000 "	3192 "
Mars		1.88085 "	7424 "
Ceres		4.60345 "	24487 "
Jupiter		11.86 "	86560 "
Saturn		29.46 "	290962 "
Uranus		84.02 "	1176765 "
Neptune		164.78 "	2888533 "

Sub-systems.

Planet	Satellite.	R_o Adopted Rotation of Planet.	P_o Observed Period of Satellite.	R_c Time of Planet's Rotation Calculated by Babinet's Criterion.
The earth	The moon	1 day	27.32166 days	3632.45 days
Mars	Phobos	$24^h.62297$	7.6542 hours	190.62 hours
	Deimos		30.2983 "	1193.53 "
Jupiter	V	$9^h.928$	11.9563 "	64.456 hours
	I		1.7698605days	14.60 days
	II		3.5540942 "	35.900 "
	III		7.1663872 "	93.933 "
	IV		16.7535524 "	290.63 "
	VI		250.618 "	10768.8 "
	VII		265.0 "	11602.4 "
	VIII		930.73 "	61997.1 "
Saturn	Inner edge of ring	$10^h.641$	0.236 "	0.6228 days
	Outer edge of ring		0.6456 "	2.383 "
	Mimas		0.94242 "	4.2902 "
	Enceladus		1.37022 "	7.0615 "
	Tethys		1.887796 "	10.822 "
	Dione		2.736913 "	17.751 "
	Rhea		4.517500 "	34.620 "
	Titan		15.945417 "	186.05 "
	Hyperion		21.277396 "	273.06 "
	Iapetus		79.329375 "	1580.1 "
	Phœbe		546.5	20712 "
Uranus	Ariel	$10^h.1112$ (Cf. A.N., 3992)	2.520383 "	33.714 "
	Umbriel		4.144181 "	65.435 "
	Titania		8.705897 "	176.05 "
	Oberon		13.463269 "	314.83 "
Neptune	Satellite	$12^h.84817$ (Cf. A.N., 3992)	5.87690 "	141.8 "

II. Table of Data Relating to the Solar System.

Planet.	Centrifugal Force, calculated from data of Babinet's criterion, present orbital centrifugal force being unity.	Density of Central Body, when expanded to fill orbit, that of atmospheric air at sea level being unity.
Mercury	0.000000253	0.001776
Venus	0.000000134	0.0002723
The Earth	0 000000098	0.0001029
Mars	0.000000064	0.00002913
Ceres	0 000000035	.....
Jupiter	0.000000019	0.000000732
Saturn	0.000000010	0.000000118
Uranus	0.0000000051	0.0000000146
Neptune	0.0000000032	0.0000000038

III. Table of Data Relating to the Satellite Systems.

Planet.	Satellite.	Centrifugal Force, calculated from data of Babinet's criterion, present orbital centrifugal force being unity.	Density of Central Body, when expanded to fill orbit, that of atmospheric air at sea level being unity.
The earth	The Moon	0.00005657	0.01965
Mars	Phobos	0.001612	1151.
	Deimos	0.000644	73.05
Jupiter	V	0.034408	58 93
	I	0 014694	4.66
	II	0.009277	1.15
	III	0.005820	0.285
	IV	0.003323	0.0523
	VI	0 0005416	0.000232
	VII	0.0005217	0.000208
	VIII	0.0002254	0.0000169
Saturn	Inner Ring	0.1435	
	Mimas	0.048254	16.45
	Enceladus	0 037651	7.61
	Tethys	0.030436	4.11
	Dione	0.023772	1.96
	Rhea	0.017017	0.717
	Titan	0.0073449	0.0576
	Hyperion	0.0060716	0.0324
	Iapetus	0.0025205	0.00232
	Phoebe	0.0006962	0.000049
Uranus	Ariel	0.0055888	2.40
	Umbriel	0.0040111	0.88
	Titania	0.0024454	0.200
	Oberon	0.0018287	0.082
Neptune	Satellite	0.0017177	0.43

It should be noticed that the centrifugal force varies as the square of the velocity divided by the radius. Thus in the case of the earth, actual revolution in the orbit occupies one year, whereas the hypothetical nebulous sun expanded to fill the

earth's orbit requires 3192 years for a rotation; and the rotational centrifugal force therefore is only 1: $(3192)^2$ of what is required to detach the earth, or less than a ten millionth part. In the case of Neptune, the calculated time of rotation for the expanded central nebula by Babinet's criterion, is 2,888,000 years, whereas Neptune actually revolves in 165 years. The calculated time of rotation is thus 17,500 longer than the observed time of revolution; and the rotational centrifugal force is therefore only 1:$(17500)^2$ or 1:306,250,000 of the centrifugal force required to detach Neptune.

In view of these facts we know that the planets never were detached from the sun by acceleration of rotation as held by Laplace and long believed by astronomers; but on the contrary that they were formed independently, at a great distance, and have since approached the sun as their orbits have been made smaller and rounder and rounder under the secular action of a resisting medium.

In regard to the satellites, the case most favorable to the detachment theory is offered by the inner ring of Saturn, but even here the rotating planet, when expanded to fill the ring, gives only one seventh of the centrifugal force required for detachment. So that the theory of detachment is wholly given up, not only for the planets, but also for all the satellites of the solar system. Moreover, the retrograde satellites of Jupiter, Saturn and Neptune are easily explained by the modern Capture Theory, while they can not be harmonized with the old nebular hypothesis of Laplace, which is therefore quite abandoned by all recent investigators.*

There are at least three good reasons why the capture of satellites is inevitable: (1) The planetary rotations are not

* These statements are *positive*, because Babinet's criterion, based on the conservation of areas, is incontestable, having in the rotation of bodies the same dynamical rigor that the law of gravitation has for the orbital motions of the planets. Curiously enough prominent astronomers occasionally overlook the decisive import of these elementary mechanical principles. Thus in POPULAR ASTRONOMY, for October, 1911, p. 467, Professor E. B. Frost, Director of the Yerkes Observatory, is led to the sad conclusion that "no adequate substitute has been proposed" for the abandoned theory of Laplace. He adds that these views are shared by friends whose opinions he values, showing that they are quite unaware of the notable progress recently made, and that obscurity regarding the significance of this dynamical principle still is widespread, although carefully treated by me three years ago when I first called attention to Babinet's neglected work of 1861, and more fully developed in my *Researches*, Vol. II, a copy of which was presented to Professor Frost in October, 1910.

rapid enough to throw the bodies off, even if none of them revolved in the contrary direction, as observed in the case of the outer satellites of the systems of Jupiter and Saturn; (2) The density of of the expanded central globes would in all cases be too small to exert any sensible hydrostatic pressure outward, so that unless the angular rotation gave adequate centrifugal force, the deficiency could not be supplied by hydrostatic pressure from the centre; (3) It is found that if set in revolution with the velocity assigned by Babinet's Criterion the satellite in every case would fall into the planet before half a revolution was accomplished, (cf. Proc. Am. Phil. Soc., Vol. XLIX, No. 197, Nov., 1910, p. 356). It therefore follows incontestably that the satellites can have been set revolving in their orbits only by capture, or addition from without, which is clearly indicated also by the retrograde motion of satellites of Jupiter and Saturn.

V. How the Satellites were Captured.

In 1836 the celebrated German mathematician Jacobi communicated to the Paris Academy of Sciences an integral of the problem of three bodies in the restricted case where the system is made up of a sun attended by a planet revolving in a circular orbit; and the third body a particle of insensible mass. This is the case which is of special interest in Cosmogony, and here it has found its widest application. In 1877 the work of Jacobi was much extended by Dr. G. W. Hill in his researches on the Lunar Theory, which have been the starting point of the profound researches of Poincaré, Darwin and others on Periodic Orbits, and related topics in celestial mechanics.

Dr. Hill showed that in the restricted problem of three bodies, implied in Jacobi's integral, there is a partition of the whole space into three parts,—one about each of the large bodies, the sun and planet, and a larger domain enclosing both bodies—within which the power of control over the particle is vested in the the two bodies individually and collectively, respectively. The closed surface about the earth includes the orbit of the moon, and the orbits of the other satellites in like manner are within the closed surfaces about their several planets; and Dr. Hill remarks that this arrangement is necessary to secure stability. (Hill's Collected Mathematical Works, Vol. I, p. 330). If a satellite is once within this region, with the surface of zero velocity closed about it, it cannot escape, but will always remain attached to the planet, and its radius vector

will have a superior limit. How the moon and other satellites came within these closed regions Dr. Hill did not inquire; and subsequent investigators appear to have supposed that as these bodies cannot now escape from their planets, so also they cannot have come in from a remote distance, but must have originated where they now are. This is the view put forth by Moulton in his discussion of Professor W. H. Pickering's suggestion that Phoebe had been captured by Saturn (Astrophysical Journal, October, 1905, p. 178); but such reasoning is easily shown to be erroneous by the following considerations:—

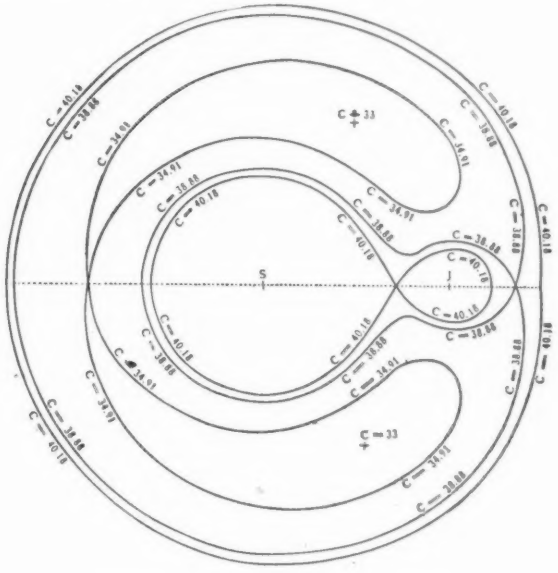
Jacobi's integral, as originally given by hin, is based on the differential equations for unrestricted motion in empty space, and no account is taken of the additional terms which must be added to the differential equations of the motion of the sun planet, and particle, when the motion is very slightly conditioned by the introduction of a nebular resisting medium, such as existed in the early history of our system, and is now observed to be widely diffused throughout nature. Jacobi's original integral, therefore, requires the addition of a secular term to represent the actual movement of a sun, planet, and particle; and the complete expression for any particle whose coördinates are x_i y_i z_i, becomes—

$$x_i^2 + y_i^2 + \frac{2(1-\mu)}{\sqrt{(x_i - x_1)^2 + y_i^2 + z_i^2}} + \frac{2\mu}{\sqrt{x_i - x_2)^2 + y_i^2 + z_i^2}} = C_i + \alpha_i t_i \ldots (1)$$

The secular term α_i t_i makes the constant C_i increase with the time.

Now the surfaces of zero relative velocity, which define the closed spaces about the planets, have larger values of C_i the nearer we approach to the sun or planet. This is easily seen in the accompanying plate from Darwin's celebrated memoir on Periodic Orbits (Acta Mathematica, Vol. XXI). When the particle or satellite revolves against resistance, therefore, the second member of (1) increases, and there is a secular shrinkage of the surface of zero relative velocity. Accordingly the particle drops down nearer and nearer these centers, and the surface finally becomes closed, leaving it no longer free to move about both bodies in the hour-glass shaped space, as formerly, but restricted to the sphere of influence controlled by the sun or planet individually, as the case may be. The particle which once revolved about both the sun and planet can no longer do so, but becomes an inferior planet (satellite of the sun) or a satellite of the planet.

This is how the satellites of the solar system were captured. At first they moved principally under the attraction of the sun, and could pass from the sun's to the planet's domain, through the neck of the hour-glass shaped space connecting the two spheres of influence. When the neck is narrow, Darwin says that a particle which passes from the sun's to the planet's control may revolve about it hundreds of times before quitting the planets sphere to return again to the sun's control. And if resistance is meanwhile encountered, so that the neck of the surface of zero velocity becomes closed, it is clear that the particle never will quit the sphere of the planet's control, but will abide there permanently as a satellite.



CURVES OF ZERO VELOCITY (DARWIN)

This diagram illustrates the hour-glass shaped space through which the particle may move and drop down nearer the sun or planet, till it becomes captured by one of the larger bodies.

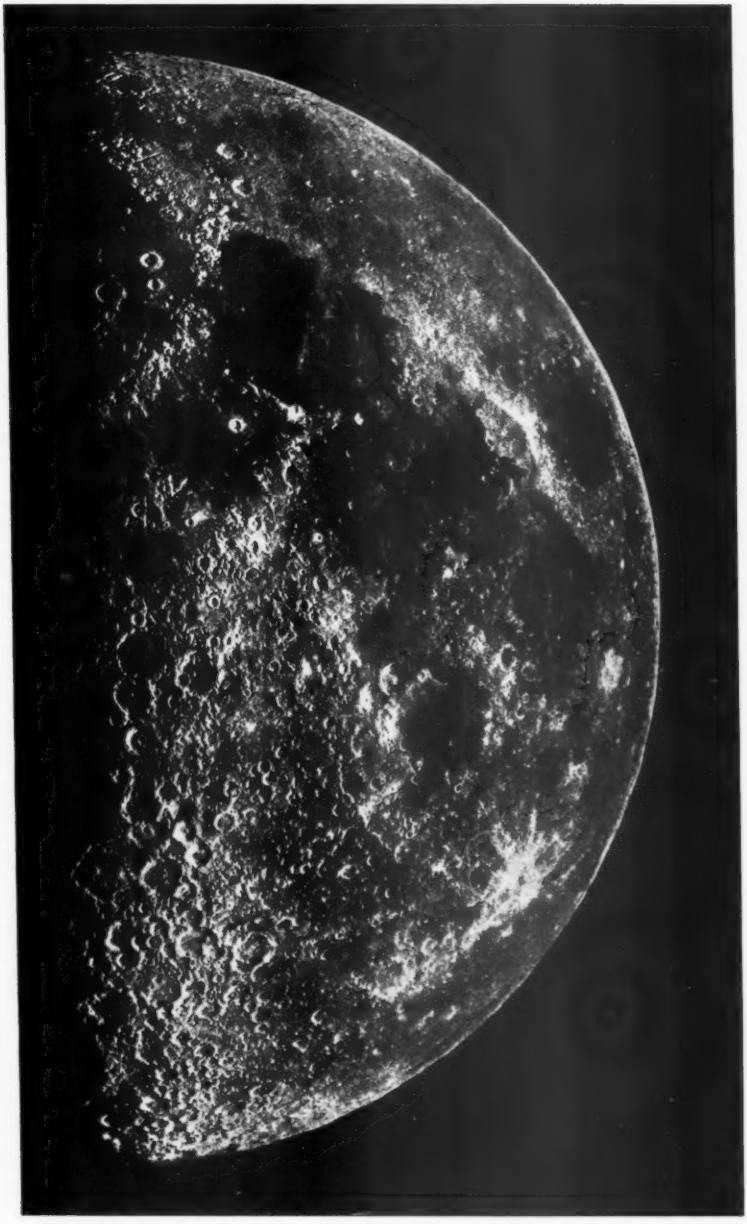
Thus it incontestably follows that the satellites of Jupiter, Saturn, and other planets formerly moved about the sun, and since they were captured have had their orbits reduced in size and rounded up under the secular action of the resisting medium formerly pervading our solar system. Satellites may cross over

the line S J before coming completely under the planet's control, in which case they will move retrograde. In such cases the neck connecting the two spaces is extremely narrow. But as the neck usually is not so narrow as to produce crossing satellites, most of them naturally move direct, in accordance with observation. This is the reason also why the planets have direct rotations on their axes. The planets have in no case been inverted, as some have recently supposed, in order to account for the retrograde motion of the satellites of Jupiter and Saturn.

VI. Capture Theory of Satellites Independently Confirmed by Brown and Poincaré.

The above discussion is substantially that given by the writer in the *Publications of the Astronomical Society of the Pacific* for August, 1909. The subject has since been treated more in detail and from a slightly different point of view by Professor E. W. Brown in the *Monthly Notices* of the Royal Astronomical Society for March, 1911, p. 453. Brown considers the oscillations of an asteroid about the triangular points, where Lagrange showed that there are particular solutions of the problem of three bodies, and a small body may revolve in stability when the asteroid is subjected to small disturbances, as under the action of a resisting medium. Brown shows that it will revolve in periodic orbits about the triangular point, but the constant C of the Jacobian integral will steadily increase and the periodic orbits increase in size; and finally it will reach a critical stage corresponding to the equilibrium point in opposition to Jupiter, where Lagrange showed that another particular solution of the problem of three bodies exists. Under disturbances all these solutions are unstable, and for values of C well beyond this critical value, Brown adds that the orbits "consist (1) of an inner planetary orbit making complete revolutions round the sun in the positive sense; (2) of an outer planetary orbit making complete revolutions round the sun in the negative sense relative to the moving axes; (3) of a satellite revolving round Jupiter in the positive sense." In other words, an asteroid passing through these equilibrium points with suitable velocity corresponding to the critical value of C, may pass under the control of Jupiter and become a satellite of that planet, as I demonstrated in 1909 (A. N. 4341-42).

PLATE XVIII.



THE MOON, EIGHT DAYS OLD, PHOTOGRAPHED BY LOEWY AND PUISEUX AT THE PARIS OBSERVATORY, FEB. 13, 1894

(From *Atlas Lunaire*, Plate A. Naked Eye View.)

Finally it remains to add, as already pointed out, that the capture of satellites has been treated also by Poincaré in his course at the Sorbonne during the present year, which is being published and will appear in November. Astronomers and mathematicians naturally will be interested in the forthcoming work of this great master of celestial mechanics. In a recent letter he tells me that he insists on the capture of planets as satellites under the action of a resisting medium.

It is worthy of remark that as far back as 1906 Professor Elis Strömgren, now of Copenhagen, while occupied with the motion of three bodies made a very similar investigation of the problem of cusps and loops, and obtained some remarkable results (*Astron. Nachr.* No. 4155) which are now found to confirm the capture of satellites.

From this brief outline it will be seen that the Capture Theory of satellites is now established and very generally accepted by the leading authorities in this difficult branch of mathematical astronomy.

VII. The Origin of the Retrograde Revolutions of the Satellites and of the Direct Rotations of the Planets on their Axes

In my work of 1909, quoted above, it was shown how the retrograde motion of the satellite could arise, by the body crossing over the line S J in passing through the neck of the hour-glass space before it came under the control of the planet. It may arise also in other ways. We have seen above that in passing through the equilibrium point, in opposition to Jupiter, the satellite usually will move direct, because there is a space of finite extent in this region corresponding to the critical value of the Jacobian integral, and unless the disturbance is considerable, the gradual transition will give a direct revolution: but if the disturbance be larger, at this critical stage, the satellite may be driven beyond the center of the equilibrium point and set revolving in a retrograde direction. This result is very similar to the case (2) above quoted from Brown's paper, where he concludes that the asteroid may make complete revolutions around the sun in the negative sense relative to the moving axes.

We need not dwell at greater length on the motions of satellites. It is obvious that they may move either direct or retrograde, as first pointed out by me in 1909. But if most of the satellites have direct motion, those which are retrograde will

be likely to be destroyed, unless they are so situated as to escape serious collision. It is remarkable that the retrograde satellites of Jupiter and Saturn are on the outside of their systems, where they could easily survive; and this no doubt is the secret of their escape from destruction. Probably they were captured quite late in the history of the solar system, when the resisting medium was relatively ineffective, as shown by the rather large surviving eccentricities of their orbits.

And now just as the satellites usually have direct orbital revolutions, so also do the meteorites and other small masses of cosmical dust circulating in the vortices about the planets, of which the satellites alone are large enough and bright enough to be visible in our telescopes. When swarms of this dust collide with the planet, therefore, the tendency is to give the globe a direct rotation on its axis, because the number of particles having direct revolution greatly predominates over those having retrograde revolution. This is the secret of the direct rotations of the planets on their axes; and wherever the down pour of dust is appreciable the axial rotations are being accelerated. It is not strange therefore that the sun, Jupiter and Saturn have equatorial accelerations, which long proved bewildering to astronomers.

VIII. The Obliquities of the Planets.

The problem of the obliquities of the planets long presented great difficulty to the astronomer, and was not solved till 1908, when it was shown by the present writer that it is determined by the capture and absorption of small bodies revolving about the sun in planes nearly coinciding with the orbits of the planets. The countless collisions of these small bodies with a planet like the earth are illustrated by the meteors vaporized in our atmosphere to the number of over a billion daily. In a century this dust would make a layer a millimeter thick all over the globe. The same down pour of cosmical dust occurs on the other planets, and often times the masses are larger than those now swept up by the earth, as we see by the embedded satellites which produced the lunar craters.

As they revolve about the sun in orbits, which on the average are not much inclined to the orbit of the earth, the tendency is to tilt the earth's axis into a position at right angles to the plane of the ecliptic. The obliquity thus tends to vanish, as illustrated by Jupiter, the greatest of the planets,

which has thus acquired a very small obliquity of some 3°, from the capture and absorption of comets, asteroids and satellites. The almost zero obliquity of Jupiter shows the normal development of the process. As a test of the theory it was shown by actual calculation that Saturn would have the present obliquity of some 28° nearly destroyed if the mass of that planet were trebled, to become equal to that of Jupiter, by the same process of the capture and absorption of small bodies moving near the plane of the planet's orbit. The increase of the obliquities from Jupiter to Saturn and Uranus therefore is natural, and in accordance with established theory. Within Jupiter's orbit the obliquities decrease from Mars (24.5°) to the earth (23.5°) and Venus (12° or 15°); and the rotation periods also decrease from $24^h\ 37^m\ 22^s$ in the case of Mars, to $23^h\ 56^m\ 4^s$ (sidereal day) for the earth, and $23^h\ 21^m$ for Venus. The order thus existing among the terrestrial planets shows that they have been formed by a very regular cause which has produced harmonious effects.

When the nuclei of the planets were first formed far from the sun, they may have rotated in almost any planes, determined by the collisions previously experienced; but as they drew nearer the sun the rotations became direct and more and more harmonious, as now observed. Beyond a doubt this is the true explanation of the obliquities of the planets of our solar system; and similar laws operate to establish corresponding obliquities for the planets revolving about the fixed stars generally. Accordingly it follows that the planets attending the fixed stars have seasons and alternation of day and night, such as we are familiar with, and therefore they are habitable by living beings like those observed on the earth.

(To be continued.)

GRAVITY AND THE EARTH'S MOTIONS.

(Copyright, 1911, by HYLAND C. KIRK.)

The Earth's three movements—Their assigned causes—Our Knowledge of Gravitation—Planes of possible collapse—Direct Causes of Gravity and the Earth's Rotation—The Earth and Moon—Centers of Impulse and of Gravity—Other Planets—Maskelyne, Hutton and Playfair's Experiment—Spheres in juxtaposition—Professor Crooke's Experiment—Shifting of the Pole—Conclusions.

Assuming that gravitation is a pressure as illustrated in the top and gyroscope, it follows that before we can fully or satisfactorily understand it, we must measurably understand how it affects the earth to induce its various movements.

The earth has three motions. As the earliest probably of these it is moving forward with the sun in space. In 1783, Sir William Herschel discovered that the great mass of the fixed stars appear to be moving from the direction of the constellation Hercules, toward that of the constellation Argus. Argelander, Struve, Galloway, Madler and others have verified that observation, determining that the sun and its system of planets are moving forward in space at the rate of about 57,600 miles per hour around some center which is so remote that they do not traverse one minute of arc in a thousand years. The earth is also revolving around the sun; and third, it is rotating on its axis.

Gravitative attraction has been assigned as the cause of this forward movement of the earth with the sun in space, as well as the cause of the earth's revolution around that luminary, while its rotation on its axis has been usually ascribed to an original impulse due to nebular rotation.

Our most immediate knowledge of gravitation is in relation to the weight of bodies on the earth. If the same body is weighed at various points between the equator and one of the poles, it is found that its weight increases as we go toward the pole and vice versa. According to observations deduced from vibrations of the pendulum, a body weighing 194 pounds at the equator, weighs 195 pounds at the pole. Thus it is seen that the same body is not drawn toward the earth with the same force in all situations. This variation for the most part is attributed to the action of centrifugal force which as related to the earth's rotation, increases as we go from the pole toward the equator. The action of this same force is also used to explain why a southward flowing stream such as the Mississippi flows uphill, or in other words empties at a point farther removed from the earth's center than its source.

It is noticeable that this force which induces a body to fall toward the earth with greater weight at one of the poles than at any other point, if increased sufficiently would cause the mass of the earth to collapse and spread out in the form of a plane passing through the equator and at right angles to the earth's axis or polar diameter. It is computed that if the earth's rotative velocity were increased seventeen times such a

result would follow, and we must suppose that the tendency of bodies at the poles to fall toward the earth would in that case be proportionately increased, not because of any inherent attraction but as the result of the forces inducing increased rotative or centrifugal motion.

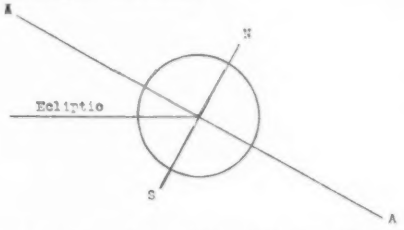


FIGURE 1. From the earth's rotation on its axis.

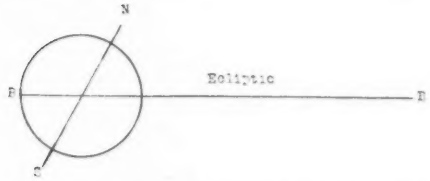


FIGURE 2. From the earth's revolution around the sun.

FIGURE 3. From the earth's movement with the sun in space.

PLANES OF DIFFUSED MATTER WHICH MIGHT RESULT FROM AUGMENTED STRESS OR STRAIN OF THE EARTH'S SEVERAL MOTIONS— SHOULD THE PLANET COLLAPSE.

Where rotation is induced by two or more forces severally affecting the mass of a given body, each force has its own

effect in the form of a stress or strain, which in a globe may be represented as a plane passing through its center. If such a stress known as centrifugal force, which is the very opposite of attraction, affects and enters into the action of gravity everywhere on the earth's surface, the result of our planet's rotation, as the earth has other motions, it becomes interesting to know just how far gravitation as related especially to the phenomena of weight and falling bodies is affected by these other movements.

It may be noticed that the strain of the earth's mass in its revolution around the sun, acts at a different angle from the strain of its revolution on its axis. As the latter if increased sufficiently would cause the earth's particles to assume the form of a plane coincident with and extending in every direction from the equator (A—A, Figure 1.), so the former if increased sufficiently, would force the earth's mass to collapse in the direction and shape of an elongated plane coincident with the ecliptic (B—B, Fig. 2).

The earth's movement along with its great primary in the direction of the constellation Hercules of the northern heavens, indicates the influence of a strain tending to collapse and diffuse the earth in still a third direction, which may be represented by an elongated plane nearly perpendicular to the ecliptic (C—C, Figure 3.)

It is evident then, that the increased tendency observed of a body at the pole over a body at the equator as influenced by centrifugal force to fall to the earth, is not the full measure of that tendency, its full influence not being shown because constantly opposed by other forces of the same general character. And here the question arises, may not these unrecognized forces in combination constitute what we call gravitation upon the earth? To be perfectly clear, may not the rotation of the earth on its axis, as well as its shape, be due to the forces inducing its other two movements? Here are two forces acting nearly at right angles to each other as affecting the earth: one propelling it around the sun and the other driving it forward with the sun in space, the result of which is seen to enter to some extent into what is called gravity, while their full effects are necessarily counteracted, equalized, and thus concealed from observation in the resulting rotation of the earth on its axis.

Now whatever these external forces are, or however they may originate in space, on the principle that a dog is stronger than its tail—to use a homely illustration—it is much more

probable that the greater controls the less, and that gravitation is the resultant of these external forces of the Universe, than of any inherent attraction in the earth or matter itself.

Since Newton advanced the hypothesis scientists have generally regarded the compression of the earth at the poles and bulging of its equatorial parts, as due to the centrifugal force of its rotation on its axis, but without usually ascribing to the stress due to its other movements any virtue toward modifying the earth's figure. That this is a mistake and that the same forces involved in the earth's revolution around the sun, combined with those of its movement with the sun in space, have an all-important influence in determining not only the shape of our planet, but of the sun itself and every other planet, is strongly suggested by an examination of the principles of rotation and their effects as manifested by the earth. The fundamental laws of stress in rotating bodies are two:

> 1—It increases as the square of the velocity of the given body. "With a string of given length, if the velocity is doubled, the strain upon the string (the centrifugal force) is four times as great, and the strength of the the string (the centripetal force) needs also to be four times as great."
>
> Olmstead's Astronomy, page 55.
>
> 2—It "varies as the radius of the circle divided by the square of the time of revolution. The attraction to the center must be increased as the radius is increased. If a string is twice as long, it must have twice the strength, in order to whirl a ball at the same rate of revolution." Id. p. 56.

According to these laws the centrifugal force of the earth's revolution around the sun may be computed as nearly one-fifth as great as the centrifugal force of its rotation on its axis; and however slight the influence of the centrifugal force of its movement with the sun in space, these two external forces may be shown to be sufficient to cause the earth's rotation on its axis without the hypothesis of an original projectile force as the cause. It is a well-known principle of dynamics that when a body is acted upon by any number of impulses, of which the resultant does not pass through the center of gravity, the body will have in consequence, a double motion: first the center will move as if the forces were immediately applied to it; secondly, the body will turn as if this center were absolutely fixed.

The earth is an excellent illustration of this principle as the impulse of its revolution around the sun, is found to be located at a considerable distance from its center. The earth's entire orbit (596,904,000 miles), divided by the complete path of its rotative motion, that is, its progressive motion in 366 sidereal days (25,020 times 366), shows that the former is over 65 times as large as the latter; and this indicates that the center of impulse is about 1/163 part of the earth's radius, distant from its center of gravity. According to Baron Madler's theory, the sun and its satellites move in an orbit whose radius is 34 million times as great as that of the earth's orbit—the solar system though moving with a velocity of 57,600 miles per hour, yet making its revolution around this greater center in about 78 million years. So that the absolute force causing this forward movement of our system in space, is quite sufficient when combined with the force inducing solar revolutions, to cause the rotation on its axis of each spherical body whose center of impulse does not coincide with its center of gravity; as well as to determine the character of the rotation in each case according to the location of, and distance between these two centers.

As fully sufficient then to induce the force of its rotation on its axis, the earth is seen to be subject to the stress of two other forces, the one arising from its revolution around the sun with a velocity of 68,000 miles per hour and the radius some 93 million miles, and the other from its movement with the sun at the rate of 57,600 miles per hour, about some center, said by Madler—though without much foundation—to be the star Alcyone of the Pleiades, with a radius of revolution so infinitely great, that the whole diameter of the earth's orbit in comparison is but a mere point!

The stress of the earth's revolution around the sun affecting its mass in a plane coincident with the ecliptic, and the effect of the earth's movement with the sun being exerted in a plane at right angles to the ecliptic, the resultant of these two forces must not only cause the earth to revolve on its axis, but the stress of the earth's rotation on its axis being to impel the particles from either pole toward the plane of the equator, the resultant of these three motions and the forces producing them, is sufficient to impel every particle of the earth toward its center where these planes of stress intersect. Accordingly the earth rotates on its axis as the result of these two external forces, and with this added motion equalizing the effects of

these external pressures, it coheres in nearly a spherical mass, and bodies fall toward its center with very nearly the same rate of velocity everywhere on its surface. (Figure 4).

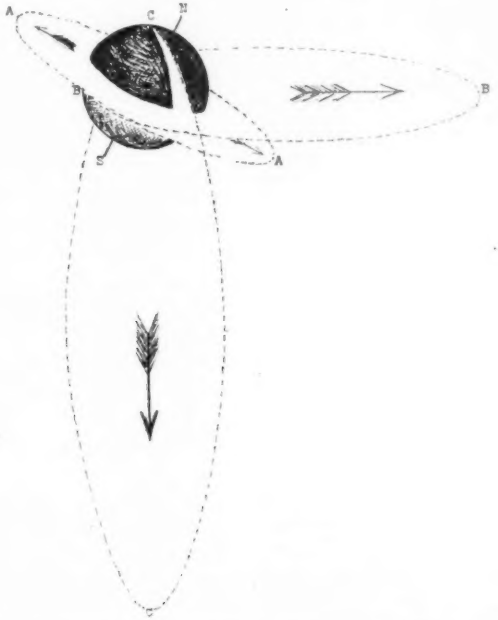


FIGURE 4. Combination of planes of augmented stress, illustrating the grip with which the earth is held together by external forces, constituting terrestrial gravitation.

The same influences being exerted on the moon, the latter must act in accord with the reactions set up by its more powerful companion, thus causing our luminary to rotate but once in its circuit about the earth. And so the moon's apparent influence on the tides is a coincidence so far as it may be interpreted as an attraction, the active cause being the momenta of the earth and moon as related to the fulcrum of their rotation in combination with the earth's diurnal and solar motions, acting on the mobile waters of the ocean. The earth's mass being some eighty times that of the moon, the fulcrum of their rotation is within and at a considerable distance from the surface of the earth, so that as they swing reciprocally round each other, on the side nearly opposite to the moon where the centrifugal force of the earth's rotation coincides

with this movement, the water—certainly not influenced there by the moon's *attraction*—is necessarily and constantly massed; on the opposite side and nearer the moon, though not at its nearest point (Figure 5), through the same influences exerted at the same time, a similar massing of the water occurs.

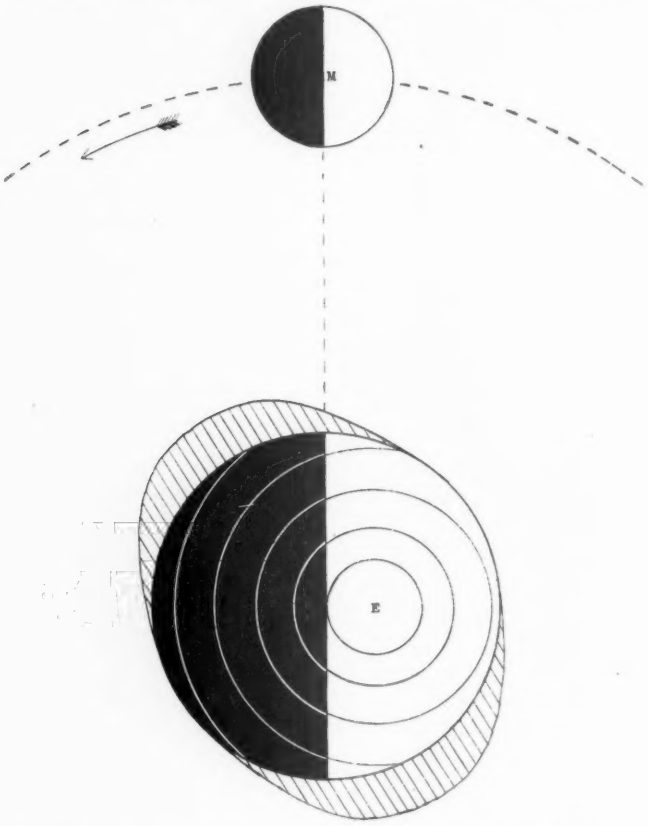


FIGURE 5. Illustrating the massing of water on both sides of the earth at the same time, not as the result of the moon's *attraction*, but from the momenta of the two spheres as related to the fulcrum of their rotation.

Here is suggested the reason also why the nodes of the equator and ecliptic, coinciding with the equinoxes, are slightly shifted each annual revolution; because of the slight shifting of the position of the center of impulse or impact of the earth

in its revolution around the sun as related to its center of gravity, due to all the cosmic conditions. In the influencing of one body by another, the principles of mechanics, by way of ensuring accurate results, contemplate that such action shall be exerted through the centers of gravity of the respective bodies; but in the common view of precessional influence, the equatorial ring of the earth is made to assume all the importance of a separate body. As this equatorial protuberance is itself attributed to the action of centrifugal force operating from within, a true explanation would seem to lie in the direction of illustrating how the earth's center is affected to produce this precessional result. The fact that the center of impulse in the earth's movement varies from its center of gravity, thereby causing its rotation: that all the bodies of the solar system exert mutual reactions upon each other, as a consideration of the forces of space must show; and that the sun and moon, the former because of its size and activity, and the latter because of its nearness, necessarily affect the earth most—all these considerations have to be taken into account in this estimate, it is true: but the mode of operation is suggested by the phenomena afforded by the top in its various forms, and also by certain movements of the planets themselves.

Professor James Elliot appears to have been the first to construct a top with its center of gravity below its point of support, which precesses in the same direction as the earth's nodes. Admittedly every free moving body in rotation precesses according to the relation between its center of gravity and fixed point or center of impact, and there is no good reason why the earth's precession should not be in accord with this general principle. Indeed we must believe that the direction of movement of a planetary body could be entirely reversed by a change in the direction of "the fixed point" as related to the center of gravity on the one hand and impelling forces on the other. All the planets rotate upon their axes and revolve around the sun in the same direction from west to east, and all their satellites revolve in the same direction around their primaries, except those of Uranus and Neptune, whose moons revolve around their respective primaries from east to west; a circumstance which may be best explained on the supposition that their centers of impact as related to their centers of gravity are located on the opposite side from that of the other planetary bodies.

That gravity is not an attraction seems the more probable, because immediate physical agencies are apparent here, while the evidence for attraction is altogether lacking. "You sometimes speak of gravity as essential and inherent to matter," says Newton in one of his letters. "Pray do not ascribe that notion to me, for the cause of gravity is what I do not pretend to know." Yet for nearly two centuries, his followers have been ascribing the theory of "attraction" to Newton, the very thing he warned them not to do. According to his view we must have a definite conception of definitely applied forces, before we can feel at all certain that we have a correct conception of gravitation.

Certain experiments made with a view proving attraction in matter as the cause of gravity, when fairly interpreted seem to indicate quite a different cause. From the inclination of plumblines suspended on either side of the Schiehallien mountain, Maskelyne, Hutton and Playfair sought to prove experimentally that bodies attract each other directly as their masses. Such inclination of bodies toward each other when suspended from great heights, has been demonstrated to be due simply to their radial tendency toward the earth's center; while any tendency of small bodies suspended in the near neighborhood of large ones to approach the latter, not due to this cause, may be better explained by the very probable interception of pressure in the intervening medium, than by the hypothesis of attraction.

Cavendish, Reich, Bailey, and others at different times, have presented as experimental evidence of attraction, the fact that spheres of lead when suspended incline toward each other; such inclination as it is claimed being especially marked when a large and a small sphere are hung in juxta-position.

Professor Wm. Crookes, who made numerous experiments of the most delicate character by means of his radiometer, "in the endeavor to trace some connection between the movements of attraction and repulsion and the action of gravitation in Cavendish's celebrated experiment," found "that a heavy metallic mass, when brought near a delicately suspended light ball, attracts or repels the ball under the following circumstances:

I. *When the ball is in air of ordinary density.*

a. If the mass is *colder* than the ball it *repels* the ball.
b. If the mass is *hotter* than the ball it *attracts* the ball.

II. *When the ball is in a vacuum.*

a. If the mass is *colder* than the ball it *attracts* the ball.

b. If the mass is *hotter* than the ball it *repels* the ball.

He says in conclusion: "I have not been able to get distinct evidence of an independent force (not being in the nature of light or heat) urging the ball and mass together."

Professor Airy in his experiments with the pendulum at Harton Colliery found the intensity of gravity at the bottom of the mine, 1256 feet below the surface, to be greater than at the surface by about one part in 19,000. As the mass of the earth had decreased below the weight and increased above it, the result should have been the reverse if attraction were the cause. As the weight is found to increase in all experiments like Professor Airy's the deeper the earth is penetrated, the result is exactly what might be expected from planes of force cutting each other at the earth's center, and hence the increase in weight as that point is approached. Though supposing what is probable, that the earth's density increases as we go toward the center, it will not account for the loss in *attractive* power of 1256 feet of earth and more besides, as in Professor Airy's experiment; yet curiously enough this very experiment is commonly interpreted as an evidence of attraction.

While it is true that the positions of the planets are so adjusted to each other, in regard to their respective distances and gravitative tendencies toward the sun, and their velocities and periodic times of revolution around the sun, that if a single relation between two planets is known, the remainder may be calculated, this is no evidence of attraction; but rather of the unity of force, and suggests that a body's center of impact may be affected by many influences. The fact that all the planetary orbits are ellipses, is an evidence that their centers of impact are more or less distant from their centers of gravity; and this accounts for the wide range as to eccentricity of the celestial orbits, varying from the very slightly elliptical orbit of Venus to the cometary orbits of vast eccentricity.

The fact too that each celestial body exerts an influence upon every other indicates the vast number of tendencies to precession which each possesses and which may be exhibited in changes of position and time of its nodes or in changes of direction in its polar axis. Thus the earth exhibits precession 5/7 of which is attributed to the sun's influence, and 2/7 to the moon; nutation or wabbling of the pole, attributed to the unequal action of the moon in its circuit around the earth,

and other similar tendencies. Professor S. C. Chandler, from observations covering some fourteen years, recently found that not only is the earth's axis changing direction in the heavens but moving around on the surface of the globe; so that by this time the place of the North Pole may not be where it was when recently discovered!

The conclusion from observation and experiment is that the earth's motions are induced under the general laws of the Universe, and directly determined by forces in space which cause the earth to cohere and rotate as a globe; and an analysis of the facts disclose that no reliable evidence of an attraction in matter exists.

RADIAL VELOCITY OF HALLEY'S COMET AS DERIVED FROM A SPECTROGRAM.*

EDWIN B. FROST.

Opportunities for determining the radial velocities of comets from spectrograms have been infrequent. Unless the surface brightness is considerable, the light received through a slit-spectrograph of large dispersion is insufficient to furnish a satisfactory spectrogram.

Of course the velocity could be derived from the displacements of either the bright bands or lines, or the Fraunhofer lines in the solar spectrum reflected by the comet. If both were present in sufficient strength, it is probable that both would be measured, with the presumption that the velocity derived from the Fraunhofer lines would be the more reliable, on account of the difficulty of setting on the edges of bands.

Although several attempts were made on nights that fell to the Bruce spectrograph, there was but one date on which a satisfactory plate of Halley's comet was obtained with that instrument, namely on May 24, 1910, taken with one prism.

A wide slit was used and the Fraunhofer lines are consequently too broad for very accurate measurement.

I was able to make tolerably good settings on ten lines, however, from which a radial velocity of + 55 km per second was

* Read at the Ottawa Meeting of the Astronomical and Astrophysical Society of America, August 25, 1911.

deduced. This differs less than a kilometer from the radial velocity inferred from the ephemeris of the comet, as it was then receding from the earth.

The close agreement of the two results is accidental, as the velocity measured on the spectrogram may be uncertain by a few kilometers, but the velocity from the orbit is fully confirmed.

Yerkes Observatory, Aug. 21, 1911.

A SIMPLE METHOD FOR ADJUSTING THE POLAR AXIS OF AN EQUATORIAL TELESCOPE.

FRANK SCHLESINGER.

Methods for adjusting the polar axis of equatorial telescopes that are provided with right ascension and declination circles may be found in any work on Practical Astronomy. The present method deals especially with telescopes in which such circles are lacking. The process is a very simple one and has very possibly occurred to others, but I have never seen it in print; and in any case, it may be well to give it here as it seems to have been found useful by those who have tried it at my suggestion.

In some telescopes, the maker has provided a *latitude circle*. When the plate at the head of the tripod or pier has been leveled, and this circle has been set to correspond to the latitude of the station, the polar axis is at the proper elevation. It remains only to put it into the proper azimuth. The observer now points the telescope at a star when it is, say, just fifteen minutes east of the meridian. In these latitudes, a star that is between 10° and 30° north of the equator is best for the purpose. It will be sufficient to make the star cross the estimated center of the eye-piece field in the vertical direction, although, of course, if the eye-piece is provided with cross-wires, so much the better. The declination axis is now clamped. Half an hour later, when the star has gotten fifteen minutes west of the meridian, the observer again brings it into view by rotating the telescope around the polar axis without disturbing the declination axis. If the star again crosses the center of the field, the polar axis is adjusted. If it is apparently below the center (it is assumed that an inverting eye-piece is

used) the north end of the polar axis must be moved to the west; if above, to the east. This process may be repeated, (with longer intervals than half an hour, if need be) until the adjustment is satisfactory.

So much for telescopes that are provided with latitude circles. Where this is lacking, the method is the same, except that in addition the observer notes where the star crosses the field when the telescope is on the meridian. If this position is a mean between the other two (fifteen minutes east and fifteen minutes west of the meridian) the polar axis is at the correct elevation. If the meridian position is apparently below the mean of the other two, the polar axis should be depressed, and vice versa.

In order to know when a star is fifteen minutes from the meridian, the observer should have the sidereal time at hand. This is usually not the case with the owner of a small telescope, and it may therefore be useful to give here the simple precepts that will enable him to find, with sufficient accuracy, the time when any star crosses the meridian.

(1) Get the right ascension of the star from the section called "Fixed Stars" in the *American Ephemeris* (page 304 and following in the 1911 edition.) (2) Add the longitude of the station west of Greenwich. (3) From the sum subtract the "right ascension of the mean sun" given on page II of each month in the first part of the Almanac. (4) From the difference subtract ten seconds for each hour in the difference. (5) From this, subtract five hours if Eastern Standard Time is used; six hours, if Central Time, etc. The result is the Standard Time at which the star crosses the meridian.

Example: At what time does Aldebaran (α Tauri) cross the meridian of a place whose longitude is $5^h\ 10^m\ 30^s$, on December 2, 1911?

(1)	Right Ascension (page 338)	4^h	30^m	53^s
(2)	Add the longitude	5	10	30
	Sum	9	41	23
(3)	Subtract R.A. of mean sun (page 201)	16	40	51
	Difference	17	00	32
(4)	$10 \times 17 = 170^s =$		2	50
	Difference	16	57	42

(5) Eastern Standard time of meridian passage is therefore $11^h\ 57^m\ 42^s$ P.M.

It is obvious that this method may be applied to large as well as to small telescopes. It can be made to give very accurate

adjustments by the use of longer arcs and by measuring in the declination direction (instead of estimating) the apparent position of the star in the three positions of the telescope. In this case, the observers must take account of refraction, if the polar axis is to point toward the true pole, and this will be especially desirable if the telescope is provided with a micrometer for measuring position angles. If, however, the telescope is to be used for photography, it may be better not to direct the polar axis to the pole, but to point a little above it. This will partly compensate for refraction and will make the cross-wires follow the guiding star more closely. In these latitudes, this can best be done by selecting a star whose declination is about 20° north, and making the setting on the meridian agree with those two hours east and two hours west, paying no attention to refraction.

Allegheny Observatory, September 1911.

A STRANGE TRANSIT.

WILLIAM F. RIGGE, S. J.

On September 8 (this year) at 7:30 P. M. Father Hagen was standing on the wall of the Vatican Observatory and looking at the full moon as it attempted to transit the dome of St. Peter's. When he first saw it, its disk was already half-covered by the dome. Knowing that the moon runs half its length in a minute, he took a fancy to time the rest of the transit.

The minute seemed rather long. Indeed, it threatened to become interminable, because the moon clung to the dome without moving at all. Stranger still, the disk was actually growing larger. And it kept on growing until it became full and round, as if its diurnal motion was being reversed. Sure enough, it really backed away from the dome, and left a clearance of a full semidiameter. And all this happened on the east side of the great dome, the middle of which was about twenty-five degrees south of east. Then, as if it had retreated for a final dash, the moon made another attempt at a transit. This time it succeeded perfectly. The whole disk gradually disappeared from view in the usual way, and after a little while emerged again as gradually and completely from behind the lantern at the top of the dome.

Old astronomer as he is, Father Hagen was quite taken by surprise. A few moments of reflection, however, reassured him that everything had gone on without doing violence to the laws of nature, and that fair Cynthia had only played an innocent trick upon an unsuspecting, and momentarily unreflecting, veteran.

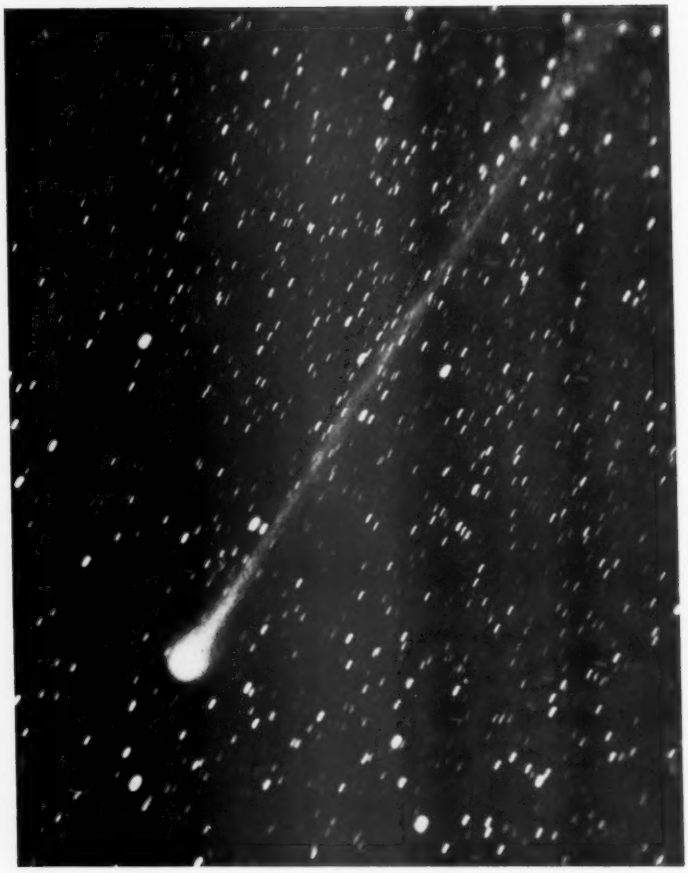
He sat down at once that same night and wrote me his experience, enclosing a diagram and a photograph to prove that his nap had been of short duration, and had given the right of way at once to the unemotional laws of mathematics. As a reparation, however, for being asleep at his post even for so short a time, he requested me to narrate the case and explain it in print.

THE DOME OF ST. PETER'S FROM THE WALL OF THE VATICAN OBSERVATORY.

This is easy enough with the aid of the photograph taken by Miss Hood, of Kansas City, Mo., a few days before the transit and from the same point of view, and with the aid of the two lines which I have drawn on the picture enclosing the moon's path in the sky, these lines being the envelope of the moving moon as a mathematician would call them, or the broad line its motion would draw on a photograph of long exposure.

This path of the moon made at the time an angle of about 48° with the horizon. It was not, of course, a perfectly straight line (or arc of a great circle), but sufficiently straight during the time of the strange transit. The diameter of the

PLATE XIX.



PHOTOGRAPH OF BROOKS' COMET, 1911 *c*, BY A. RORDAME.
ENLARGEMENT FROM ORIGINAL NEGATIVE SEPT. 18,
EXPOSURE 1 HOUR 29 MINUTES.

One of a series of photographs made with an ordinary portrait lens, guiding being done entirely by hand.

dome, 195 feet seen at a distance of about a thousand feet, was about twelve degrees. One twenty-fourth of the diameter of the dome on the picture is, therefore, the width of the moon's path. Its declination was nearly 9° south.

The rest is too simple to require further explanation. The transit was, of course, rendered so strange and remarkable by the position and shape of the great dome with reference to the moon's path in the sky. In this as in all other occurrences of life, much, if not everything, depended upon the point of view.

CELESTIAL PHOTOGRAPHY WITH ORDINARY PORTRAIT LENSES.

ALFRED RORDAME.

Perhaps the majority of students of astronomy are of the opinion that, in order to make photographs of the heavens, the very finest of apparatus must be used. While it is conceded that of two cameras, the one specially made for celestial photography by eminent opticians will produce the best results, yet good pictures can be made with ordinary portrait lenses, which nowadays may very often be purchased for a trifle at some of the older photographic studios throughout the country. The apparatus I have used in celestial photography is of the simplest possible construction, consisting of a square box of wood, painted black outside as well as inside, to which the lens, a Darlot of 3 inches aperture and of ten inches focus, is securely fastened. This box is made in two sections, one sliding within the other, making it adjustable for focusing.

It is no use trying to focus on the stars; the best way is to expose several plates, until the star trails show as the finest lines. Most portrait lenses are lacking in a flat field, and it becomes necessary to compromise on the roundness of the field and focus sharply at a little distance from the center; this will tend to make it sharpen all over, at the expense of the center.

The camera is securely bolted to the telescope and carries an ordinary 4 x 5 Premo plate holder. The telescope is equatorially mounted, and is moved by a simple tangent screw. The eye-piece is provided with crosswires, and when following a star, I put it slightly out of focus, so that it forms a disc, which may then be accurately bisected, and one of the wires

is put parallel with the motion of the stars in the field of view.

Sigma Lumiere plates are the fastest commercial plates at present obtainable. I am yet in doubt as to the advantage of backing the plates. The nonhalation brand seems to give a foggy effect. All the negatives illustrated herewith have been intensified by whitening the plates in a solution of bichloride of Mercury and afterwards immersing them in a dilute solution of Aqua Ammonia, which produces an intense black image. This treatment apparently doubles the time of exposure, and avoids fogging by the atmospheric sky illumination, produced by the glare of our electric lights, which renders a prolonged exposure impossible, at least in the cities.

The observing seat has been made as comfortable as possible, as the task of keeping the elusive star accurately centered on the crosswires is extremely fatiguing work. The equatorial stand, which I have constructed for photographing the stars, is fully described in the *Scientific American* of October 1, 1910; it is sufficiently strong to carry two or three cameras in addition to the telescope and finder.

As to the development of the negatives; the best results have been arrived at by using the developer of the maker of the plates, commencing with a rather weak developer and strengthening it as the image appears.

Salt Lake City, Oct. 15, 1911

PLANET NOTES FOR DECEMBER, 1911.

C. H. GINGRICH.

The sun's path during this month lies through the constellation Scorpio into Sagittarius. It will move southward until December 22, when it reaches its greatest declination south. This date, according to the almanac, marks the beginning of winter.

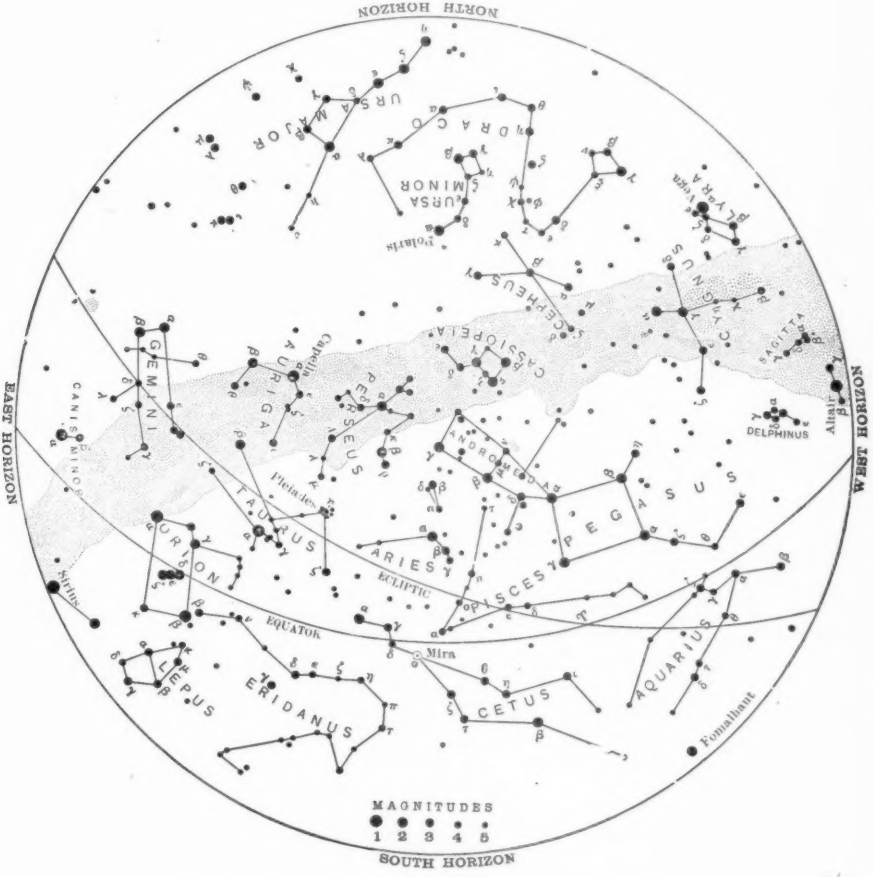
The phases of the moon for this month are as follows:—

Full Moon	Dec.	5 at 9 P. M.	C. S. T.
Last Quarter	"	12 at noon	"
New Moon	"	20 at 10 A. M.	"
First Quarter	"	28 at 1 P. M.	"

The moon will be nearest to the earth on December 6, and will be farthest from the earth on December 21.

Mercury will reach a period of greatest elongation east on December 7. At this time it will be about 21° east of the sun, and about 4° south of the sun. At and near this date it may be seen low in the southwest for approx-

imately an hour after sunset. This planet keeps so close to the sun constantly that in order to see it at all one must watch for a favorable opportunity such as this. It has quite a red appearance and can easily be recognized. After this period of greatest elongation, it will move rapidly toward the sun, and will be at inferior conjunction, that is directly between the earth and the sun, on December 24. It will be at a point nearest the sun at about this same time.



THE CONSTELLATIONS AT 9:00 P. M. DECEMBER 1, 1911.

Venus throughout the month, will move eastward at about the same rate as the sun, and will therefore maintain a position of approximately three hours west, and from about 15° north at the first of the month to six degrees north at the end of the month. During this month it will be a very brilliant

object in the morning sky. Venus is a very striking object to the naked eye when it is near its greatest elongation, as it is during this month. Though it rises very early in the morning, it would repay the effort that is necessary to obtain a view of it.

Mars will apparently be moving westward during this month. It will be in the constellation Taurus and quite near the Pleiades. It will rise about the time of sunset at the beginning of the month and earlier each day during the month. Although it will have passed its point nearest the earth it will still be quite near, and very well situated for observation. It will continue to be an interesting object to the astronomer and to the amateur because of its proximity. During the first days of the month the planet's disk will subtend an angle of about 19″.

Jupiter will reappear in the east during this month. It will rise about two and a half hours before the sun at the end of the month. At this time it will be rather near to the planet Venus. It will be an interesting sight to see these two brightest planets so near together.

Saturn like Mars, has a slow retrograde motion during the month. It is in the constellation Aries, a short distance west and a short distance south of Mars. It therefore, will also be in a very favorable position for observation, and is always an interesting object because of its unique appearance.

Uranus will move slowly eastward in Sagittarius. It will cross the meridian about an hour and a half after the sun and will be too near to the sun for observation this month.

Neptune will move slowly westward in the constellation Gemini. It will cross the meridian about one and one-half hours after midnight and may be observed conveniently during the month.

Occultations visible at Washington.

Date 1911		Star's Name	Magnitude.	IMMERSION. Washington M.T. h	m	Angle from N. °	EMERSION. Washington M.T. h	m	Angle from N °	Duration h	m
Dec.	1	*e* Piscium	5.6	13	41	82	14	36	225	0	54
	2	54 Ceti	6.0	9	05	356	9	49	287	0	44
	2	26 B Arietis	6.0	14	26	356	14	47	317	0	21
	3	29 Arietis	6.1	2	17	44	3	03	264	0	46
	3	π Arietis	5.2	11	12	28	12	16	273	1	04
	3	ρ Arietis	5.6	14	53	65	15	51	260	0	59
	4	14 H′ Tauri	6.5	5	31	99	6	17	207	0	46
	4	133 B Tauri	5.9	11	12	97	12	20	218	1	07
	4	161 B Tauri	6.5	16	49	40	17	30	303	0	40
	6	415 B Tauri	6.1	9	52	74	11	02	263	1	10
	8	28 Cancri	6.1	16	04	86	17	10	321	1	06
	10	42 Leonis	6.1	13	48	62	14	30	354	0	42
	12	ω Sagittarii	4.8	6	09	48	7	09	270	1	00
	24	37 Capricorni	5.7	5	28	86	6	34	208	1	05
	24	ϵ Capricorni	4.7	7	22	29	8	19	270	0	57
	31	54 Arietis	6.5	4	07	55	5	09	243	1	02
	31	63 Arietis	5.2	12	59	4	13	21	324	0	22
	31	65 Arietis	6.0	13	36	23	14	12	309	0	37

VARIABLE STARS.

Approximate Magnitudes of Variable Stars on Oct. 1, 1911.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R.A. 1900. h	m	Decl. 1900. °	′	Magn
X Androm.	0	10.8	+46	27	12.4*d*	V Boötis	14	25.7	+39	18	8.8
T Androm.		17.2	+26	26	12.8	R Boötis		32.8	+27	10	8.9*d*
T Cassiop.		17.8	+55	14	9.2*d*	S Cor. Bor.	15	17.3	+31	44	11.4*d*
U Cassiop.		40.8	+47	43	<13	R Cor. Bor.		44.4	+28	28	10.8
RW Androm.		41.9	+32	8	<11	X Cor. Bor.		45.2	+36	35	<12
V Androm.		44.6	+36	6	9.5	RU Herculis	16	6.0	+25	20	11.0*d*
RR Androm.		45.9	+33	50	10.2	W Cor. Bor.		11.8	+38	3	12.6
RV Cassiop.		47.1	+46	53	<14	U Herculis		21.4	+19	7	11.2
W Cassiop.		49.0	+58	1	10.2 *i*	W Herculis		31.7	+37	32	7.8
U Androm.	1	9.8	+40	11	<13	R Draconis		32.4	+66	58	9.6*d*
— Androm.		10.4	+41	12	<14	S Herculis		47.4	+15	7	11.7*d*
S Cassiop.		12.3	+72	5	9.0	RV Herculis		56.8	+31	22	10.3
S Piscium		12.4	+ 8	24	12.0	R Ophiuchi	17	2.0	−15	58	<10
RZ Persei		23.6	+50	20	10.6	Z Ophiuchi		14.5	+ 1	37	9.5
R Piscium		25.5	+ 2	22	<12	V Draconis		56.3	+54	53	<13
RU Androm.		32.8	+38	10	12.3	W Draconis	18	5.4	+65	56	9.9
Y Androm.		33.7	+38	50	11.9*d*	T Herculis		5.3	+31	0	10.6
X Cassiop		49.8	+58	46	9.2	X Draconis		6.8	+66	8	10.7
R Arietis	2	10.4	+24	35	9.4*d*	W Lyrae		11.5	+36	38	9.1 *i*
Z Cephei		12.8	+81	13	13.0	SV Draconis		31.2	+49	18	13.4
T Persei		12.2	+58	30	8,9	RY Lyrae		41.2	+34	34	11.1*d*
o Ceti		14 3	− 3	26	5.8*d*	R Scuti		42.2	− 5	49	5.2
S Persei		15.7	+58	8	<9	Z Lyrae		56.0	+34	49	10.7*d*
RR Persei		21.7	+50	49	12.8*d*	V Lyrae	19	5.2	+29	30	<13
RR Cephei		29.4	+80	42	<13	S Lyrae		9.1	+25	50	13.7
R Triang.		31.0	+33	50	6.7	TZ Cygni		13.4	+50	0	10.5
W Persei		43.2	+56	34	9.0	U Lyrae		16.6	+37	42	10.4
U Arietis	3	5.5	+14	25	<12	R Cygni		34.1	+49	58	10.9
X Ceti		14.3	− 1	26	11.4*d*	χ Cygni		46.7	+32	40	5.6*d*
R Persei		23.7	+35	20	9.0	RS Cygni	20	9.8	+38	28	8.1
W Tauri	4	22.2	+15	49	9.4	R Delphini		10.1	+ 8	47	11.2
T Camelop.		30.4	+65	57	13.0	SX Cygni		11.6	+30	46	8.6
RX Tauri		32.8	+ 8	9	12.7	V Sagittae		15.8	+20	47	10.9 *i*
X Camelop.		32.6	+74	56	12.3	U Cygni		16.5	+47	35	<10
R Aurigae	5	9.2	+53	28	8.2	S Delphini		38.5	+16	44	9.9
S Camelop		30.2	+68	45	10.4	T Delphini		40.7	+26	2	<13
SU Tauri		43.2	+19	2	9.7	T Aquarii		44.7	− 5	31	10.7
V Camelop.		49.4	+74	30	9.4 *i*	RZ Cygni		48.5	+46	59	12.0
Z Aurigae		53.6	+53	18	10.4*d*	R Vulpeculae		59.9	+23	26	<10
SS Aurigae	6	5.8	+47	46	<13	X Cephei	21	3.6	+82	40	12.3
V Monoc.		17.7	− 2	9	11.8	T Cephei		8.2	+68	5	6.0
U Lyncis		31.8	+59	57	<14	R Equulei		8.4	+12	23	12.8
S Lyncis		35.9	+58	0	12.5	T Cephei		8.2	+68	5	6.2
R Lyncis		53.0	+55	28	10.1 *i*	S Cephei		36.5	+78	10	10.2
V Can. Min	7	1.5	+ 9	2	9 2	RT Pegasi		50.8	+34	38	9 8
RR Monoc.		12.4	+ 1	17	<13	S Lacertae	22	24.6	+39	48	8.2
Y Draconis	9	31.1	+78	18	13.0	R Lacertae		38 8	+41	51	9.1
R Urs. Maj.	10	37.6	+69	18	11.3 *i*	R Pegasi	23	1.6	+10	0	8.5
T Urs. Maj.	11	31.8	+60	2	10.7*d*	V Cassiop.		7.4	+59	8	11.9*d*
S Urs. Maj.		39.6	+61	38	8.0	ST Androm.		33.8	+35	13	9.5
R Can. Ven.	13	44.6	+40	2	7.6	R Aquarii		38.6	−15	50	9.2*d*
U Urs. Min.	14	15.1	+67	15	9.1*d*	Z Cassiop.		39.7	+56	2	<13
S Boötis		19.5	+54	16	<11	R Cassiop.		53.3	+50	50	10.8*d*
R Camelop.		25.1	+84	17	9.7 *i*	SV Androm.		59.2	+39	33	<12

The letter *i* denotes that the light is increasing; the letter *d*, that the light is decreasing; the sign <, that the variable is fainter than the appended magnitude. The above magnitudes have been compiled at the Harvard College Observatory from observations made at the Amherst, Mt. Holyoke, Olcott, Swartz, Hunter, Jacobs and Hoge observatories.

Minima of Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time beginning with noon. To reduce to Central Standard time subtract 6 hours, or for Eastern time subtract 5 hours, etc. For stars marked thus * alternate minima are given; ** every third minimum; † every tenth minimum.]

SY Androm.

d	h
Dec. 31	7

*U Cephei

d	h
Dec. 1	12
6	12
11	12
16	11
21	11
26	11
31	10

*Z Persei

d	h
Dec. 3	21
9	23
17	2
23	5
29	7

RY Persei

d	h
Dec. 5	16
12	12
19	9
26	6

**RZ Cassiop.

d	h
Dec. 4	10
8	0
11	14
15	4
18	18
22	8
25	22
29	12

*ST Persei

d	h
Dec. 1	3
6	10
11	18
17	1
22	8
27	15

RX Cephei

d	h
Dec. 14	11

*Algol

d	h
Dec. 5	23
11	17
17	10
23	4
28	22

**RT Persei

d	h
Dec. 3	11
6	11
8	14
11	3
13	16
16	5
18	18
21	8
23	21
26	10
28	23
31	12

λ Tauri

d	h
Dec. 1	4
5	3
9	2
13	0
16	23
20	22
24	21
28	20

*RW Tauri

d	h
Dec. 6	12
12	1
17	14
23	3
28	16

*RV Persei

d	h
Dec. 2	12
6	11
10	9
14	8
18	7
22	6
26	4
30	3

RW Persei

d	h
Dec. 13	14
26	18

RS Cephei

d	h
Dec. 5	2
17	12
29	22

*RY Aurigae

d	h
Dec. 5	17
11	4
16	15
22	2
27	13

*RZ Aurigæ

d	h
Dec. 5	12
11	13
17	14
23	15
29	15

51.1908 Gemin.

d	h
Dec. 4	17
8	17
12	17
16	17
20	18
24	18
28	18

*RW Gemin.

d	h
Dec. 6	6
11	23
17	17
23	10
29	4

*U Columbæ

d	h
Dec. 4	0
9	15
15	5
20	19
26	10

*RW Monoc.

d	h
Dec. 4	4
7	23
11	18
15	14
19	9
23	5
27	0
30	20

RX Gemin.

d	h
Dec. 3	3
15	8
27	13

**RU Monoc.

d	h
Dec. 3	14
6	7
8	23
11	16
14	8
17	1
19	17
22	10
25	2
27	19
30	11

**R Canis Maj.

d	h
Dec. 1	13
4	22
8	8
11	18
15	4
18	13
21	23
25	9
28	19

RY Gemin.

d	h
Dec. 2	5
11	12
20	19
30	2

*Y Camelop.

d	h
Dec. 6	6
12	20
19	11
26	2

RR Puppis

d	h
Dec. 4	1
10	12
16	22
23	8
29	19

**V Puppis

d	h
Dec. 3	11
7	20
12	4
16	13
20	22
25	7
29	15

†X Carinæ

d	h
Dec. 3	9
8	19
14	5
19	15
25	1
30	11

S Cancri

d	h
Dec. 8	5
17	16
27	4

S Velorum

d	h
Dec. 5	10
11	8
17	6
23	5
29	3

**Y Leonis

d	h
Dec. 2	2
7	3
12	4
17	6
22	7
27	9

**RR Velorum

d	h
Dec. 6	10
11	23
17	13
23	2
28	16

*SS Carinae

d	h
Dec. 4	12
11	3
17	17
24	8
30	22

RW Urs. Maj.

d	h
Dec. 4	22
12	6
19	14
26	22

**Z Draconis

d	h
Dec. 1	18
5	20
9	22
13	23
18	1
22	3
26	4
30	6

*SS Centauri

d	h
Dec. 1	8
6	7
11	6
16	5
21	4
26	3
31	2

*δ Libræ

d	h
Dec. 4	7
8	23
13	14
18	6
22	22
27	13

*U Coronæ

d	h
Dec. 7	14
14	12
21	9
28	7

*SW Ophiuchi

d	h
Dec. 1	2
6	0
10	21
15	19
20	16
25	13
30	11

*SX Ophiuchi

d	h
Dec. 2	5
6	8
10	11
14	14
18	17
22	20
26	23
31	2

R Aræ

d	h
Dec. 4	4
8	15
13	1
17	11
21	21
26	7
30	18

**U Ophiuchi

d	h
Dec. 1	19
4	7
6	20
9	8
11	20
14	9
16	21
19	9
21	22
24	10
26	23
29	11
31	23

Minima of Variable Stars of the Algol Type.—Continued.

**SZ Herculis

	d	h
Dec.	1	5
	3	16
	6	3
	8	14
	11	1
	13	12
	15	23
	18	10
	20	20
	23	7
	25	18
	28	5
	30	16

Z Herculis

	d	h
Dec.	3	23
	7	22
	11	22
	15	22
	19	22
	23	22
	27	22
	31	21

SX Draconis

	d	h
Dec.	1	3
	6	8
	11	12
	16	16
	21	21
	27	1

*RS Sagittarii

	d	h
Dec.	2	18
	7	14
	12	10
	17	6
	22	2
	26	22
	31	18

*V Serpentis

	d	h
Dec.	7	21
	14	19
	21	17
	28	14

†RZ Draconis

	d	h
Dec.	3	9
	8	21
	14	9
	19	21
	25	10
	30	22

** RX Herculis

	d	h
Dec.	1	6
	3	22
	6	14
	9	6
	11	22
	14	14
	17	6
	19	22
	22	14
	25	6
	27	22
	30	14

*SX Sagittarii

	d	h
Dec.	4	5
	8	9
	12	12
	16	16
	20	20
	25	0
	29	3

*RR Draconis

	d	h
Dec.	2	16
	8	7
	13	23
	19	15
	25	7
	30	23

**U Scuti

	d	h
Dec.	3	3
	6	0
	8	20
	11	17
	14	14
	17	11
	20	7
	23	4
	26	1
	28	22
	31	18

*RX Draconis

	d	h
Dec.	4	14
	8	9
	12	3
	15	22
	19	17
	23	12
	27	7
	31	2

*RV Lyræ

	d	h
Dec.	1	9
	8	14
	15	18
	22	23
	30	4

16.1908 Vulpec.

	d	h
Dec.	4	3
	8	15
	13	2
	17	14
	22	1
	26	13
	31	0

*U Sagittae

	d	h
Dec.	7	12
	14	7
	21	1
	27	19

*Z Vulpec.

	d	h
Dec.	1	20
	6	17
	11	15
	16	13
	21	11
	26	9
	31	7

SY Cygni

	d	h
Dec.	6	17
	12	18
	18	18
	24	18
	30	18

*WW Cygni

	d	h
Dec.	5	17
	12	8
	18	23
	25	14

SW Cygni

	d	h
Dec.	2	16
	7	6
	11	20
	16	10
	21	0
	25	13
	30	3

VW Cygni

	d	h
Dec.	4	4
	12	15
	21	1
	29	11

*UW Cygni

	d	h
Dec.	1	16
	8	13
	15	11
	22	9
	29	6

W Delphini

	d	h
Dec.	4	12
	9	7
	14	3
	18	22
	23	17
	28	13

RR Delphini

	d	h
Dec.	3	15
	8	5
	12	20
	17	10
	22	0
	26	15
	31	5

RR Vulpec.

	d	h
Dec.	2	4
	7	5
	12	6
	17	7
	22	8
	27	10

**VV Cygni

	d	h
Dec.	4	9
	8	19
	13	6
	17	16
	22	2
	26	13
	30	23

**28.1910 Cygni

	d	h
Dec.	3	18
	6	16
	9	14
	12	12
	15	9
	18	7
	21	6
	24	3
	27	1
	29	22

WZ Cygni

	d	h
Dec.	3	23

*RT Lacertae

	d	h
Dec.	2	20
	7	22
	12	23
	18	1
	23	3
	28	5

*TT Androm.

	d	h
Dec.	6	8
	11	21
	17	10
	22	22
	28	11

21.1909 Andr.

	d	h
Dec.	3	0
	7	3
	11	5
	15	8
	19	11
	23	14
	27	16
	31	19

Maxima of Variable Stars of Short Period not of the Algol Type.

Unless otherwise indicated the times of maxima only are given; and the times of minima may be found by subtracting the interval printed in parentheses under the names of the stars.

SX Cassiop.

	d	h
Dec.	3	13

SY Cassiop.

	d	h
Dec.	1	24
	6	2
	10	4
	14	5

SY Cassiop.

	d	h
Dec.	18	6
	22	9
	26	10
	30	12

RW Cassiop.

	d	h
Dec.	15	2
	29	22

SU Cassiop.

	d	h
	(—0	22)
Dec.	1	18
	3	16
	5	15
	7	14
	9	13
	11	11

SU Cassiop

	d	h
Dec.	13	10
	15	9
	17	8
	19	7
	21	5
	24	4
	25	3

SU Cassiop

	d	h
Dec.	27	2
	29	0
	31	23

SV Persei

	d	h
Dec.	6	11
	17	14
	28	18

Maxima of Variable Stars of Short Period not of the Algol Type.

Continued.

RX Aurigæ		δ Gemin.		RZ Centauri		S Normæ		κ Pavonis	
d	h	d	h	d	h	d	h	d	h
(−4	0)	(−5	0)	Dec. 1	6	(−4	10)	(−4	7)
Dec. 2	13	Dec. 1	21	2	4	Dec. 8	2	Dec. 4	4
14	4	12	1	3	3	17	20	13	7
25	19	22	5	4	1	27	14	22	9
SX Aurigae		RU Camelop.		5	0	RV Scorpii		31	11
Dec. 1	18	(−9	12)	5	22	(−1	10)	U Aquilæ	
3	6	Dec. 8	8	6	21	Dec. 1	15	(−2	4)
4	19	30	15	7	19	7	17	Dec. 7	15
6	8	V Carinæ		8	18	13	18	14	15
7	21	(−2	4)	9	17	19	20	21	16
9	10	Dec. 1	8	10	15	25	21	28	16
10	22	7	14	11	14	31	23	U Vulpec.	
12	11	14	7	12	12	RV Ophiuchi		(−2	3)
14	0	21	0	13	11	Minimum		Dec. 8	8
15	13	27	16	14	9	Dec. 2	20	16	7
17	1	T Velorum		15	8	6	12	24	7
18	14	(−1	10)	16	6	10	5	SU Cygni	
20	3	Dec. 3	8	17	5	13	21	(−1	7)
21	16	8	0	18	3	17	14	Dec. 4	4
23	4	12	15	19	2	21	6	8	1
24	17	17	6	20	0	24	23	11	21
26	6	21	22	20	23	28	15	15	17
27	19	26	13	21	21	X Sagittarii		19	13
29	7	31	4	22	20	(−2	22)	23	10
30	20	W Carinæ		23	18	Dec. 3	6	27	6
SY Aurigae		(−1	0)	24	17	10	7	31	2
Dec. 3	5	Dec. 4	1	25	15	17	7	η Aquilae	
13	9	8	10	26	14	24	7	(−2	6)
23	12	12	19	27	12	31	8	Dec. 6	1
Y Aurigae		17	4	28	11	Y Ophiuchi		13	5
(−0	18)	21	13	29	9	(−6	5)	20	9
Dec. 1	6	25	22	30	8	Dec. 6	14	27	14
5	3	30	7	31	6	23	17	S Sagittae	
8	23	S Muscæ		W Virginis		W Sagittarii		(−3	10)
12	20	(−3	11)	(−8	5)	(−3	0)	Dec. 7	14
16	17	Dec. 3	20	Dec. 3	21	Dec. 4	7	16	0
20	13	13	12	21	4	11	21	24	9
24	10	23	3	V Centauri		19	12	X Vulpec.	
28	6	T Crucis		(−1	11)	27	2	(−2	1)
RZ Gemin.		(−2	2)	Dec. 5	17	Y Sagittarii		Dec. 1	10
(−1	7)	Dec. 6	8	11	5	(−2	2)	7	18
Dec. 6	8	13	1	16	17	Dec. 1	3	14	2
11	20	19	19	22	5	6	22	20	9
17	9	26	12	27	17	12	16	26	17
22	21	R Crucis		R Triang. Austr.		18	11	V Vulpec.	
28	9	(−1	10)	(−1	0)	24	5	Minimum	
RS Orionis		Dec. 1	17	Dec. 2	14	30	0	Dec. 25	20
(−2	0)	7	13	6	0	U Sagittarii		X Cygni	
Dec. 6	2	13	9	9	9	(−2	23)	(−6	19)
13	15	19	5	12	18	Dec. 2	3	Dec. 12	4
21	5	24	1	16	4	8	21	28	13
28	18	30	20	19	13	15	15	T Vulpec.	
T Monoc.		S Crucis		22	22	22	9	(−1	10)
(−9	23)	(−1	12)	26	8	29	3	Dec. 1	15
Dec. 14	1	Dec. 3	11	29	17	β Lyræ		6	2
W Gemin.		8	3	S Triang. Austr.		(−3	7)	19	12
(−2	2)	12	20	Dec. 2	17	(−3	2)	14	22
Dec. 6	12	17	12	9	1	Dec. 1	11	19	9
14	10	22	5	15	8	13	9	23	19
22	8	26	22	21	16	21	1	28	6
30	6	31	14	28	0	27	7		

Maxima of Variable Stars of Short Period not of the Algol Type. Continued.

TX Cygni		VZ Cygni		δ Cephei		V Lacertae		SW Cassiop.	
d	h	d	h	d	h	d	h	d	h
Dec. 13	9	Dec. 15	17	Dec. 4	19	(−1	10)	Dec. 2	23
28	2	20	13	10	4	Dec. 1	9	8	10
VY Cygni		25	10	15	3	6	8	13	20
(−2	14)	30	7	20	21	11	8	19	7
Dec. 2	4	Y Lacertae		26	6	16	7	24	17
10	1	(−1	10)	31	15	21	7	30	3
17	22	Dec. 5	5	Z Lacertae		26	7	RS Cassiop.	
25	18	9	13	Dec. 7	12	31	6	(−1	19)
VZ Cygni		13	20	18	9	X Lacertae		Dec. 1	17
(−1	1)	18	4	29	6	Dec. 6	11	8	0
Dec. 1	2	22	12	RR Lacertae		11	22	14	7
5	23	26	20	Dec. 6	4	17	8	20	14
10	20	31	4	12	15	22	19	26	21
				19	1	28	4	RY Cassiop.	
				25	11			(−7	10)
				31	21			Dec. 11	9
								23	12

New Variable Star 42,1911.—This is announced by A. Bemporad of Catania in *A. N.* 4524. Its position for 1900.0 is

$$\alpha = 13^h\ 25^m\ 00^s.71 \qquad \delta = -23^\circ\ 07'\ 57''.2$$

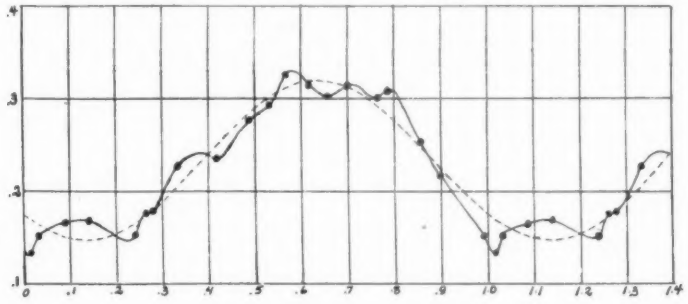
The star is B D − 22° 3604, the magnitude in the B. D. being given as 7.7. It appears to range from about 8.1 to 7.3 in a period of 8.20 days. The approximate elements are

$$\text{Maximum} = 2419207^d.4 + 8^d.20\ E$$

u **Herculis.**—In *A. N.* 4526 Mr. E. Hertzsprung gives the following revised elements of this variable star.

$$\text{Minimum} = 2410102.321 \text{ Gr. m. t.} + (E - 3056)\ 2^d.051027$$

Polaris a Variable Star.—For many years Polaris (α Ursæ Minoris) has been regarded as perhaps the most certain example of a star whose light



Light Curve of Polaris.

was constant, and it has been a fundamental reference star in the great photometric surveys at Harvard and Potsdam. A few observers, however, sus-

pected a slight variation and when Dr. Campbell discovered that the star was a spectroscopic binary with a period of $3^d\ 23^h\ 14^m$, the suspicion of its variability was greatly strengthened. In *A. N.* 4518 Dr. E. Hertzsprung gives the results of a study of 418 photographic plates of Polaris, taken in a special manner for testing the constancy of the star's light. He finds it to be a variable of the δ Cephei type with an amplitude of 0.171 of a magnitude. The probable error of the amplitude comes out ±0.012. The elements obtained are

Maximum = J. D. $2418985^d.856$ Gr. m. t. $+ 3^d.9681$ E

A comparison of an observed maximum 1910 Nov. 10.24, Gr. m. t. with the velocity curve, as extrapolated by Miss Hobe at the Lick Observatory, indicates that the maximum occurred 0.097 of the period before the time of greatest velocity of approach. This difference is not large enough to make it certain that Polaris does not agree with other stars of the δ Cephei type in having the maximum of brightness practically coincident with the maximum of radial velocity of approach.

COMET NOTES.

New Comet *f* 1911 (Quenisset):—This was discovered by Quénisset at Juvisy on the evening of September 25. Its position was

Gr. m. t.	R. A. 1855	Decl. 1855
Sept. 23.4270	$14^h\ 24^m\ 40^s$	+75° 19′

The comet is visible in an opera glass and has been moving southward from Ursa Minor, through Draco, Hercules, Corona and Serpens.

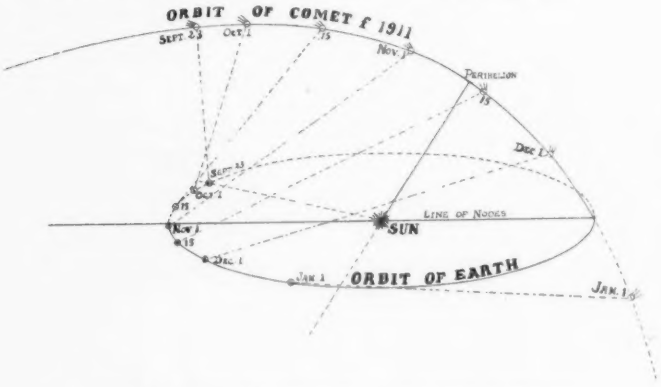
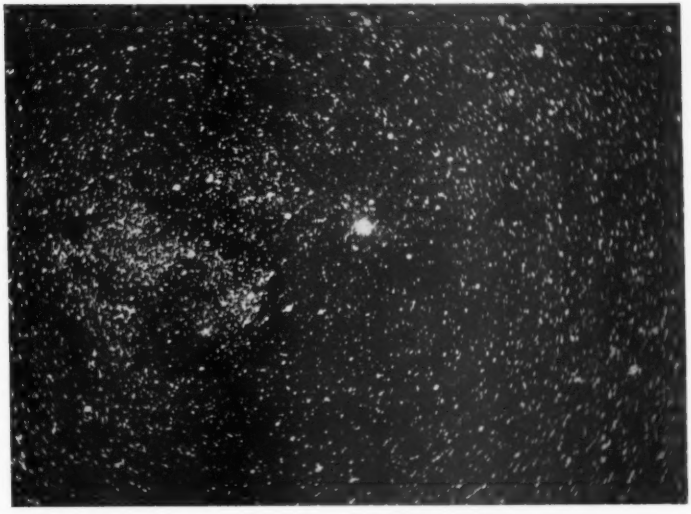


DIAGRAM OF THE ORBIT OF COMET *f* 1911 QUÉNISSET.

The following elements cabled from Kiel and distributed to American astronomers in the *Harvard Astronomical Bulletin* No. 466, and later appearing in the supplement to *A.N.* 4527, represent the course of the comet quite closely. They were computed by M. Ebell from observations at Königsberg September 24, Bergedorf September 25 and Copenhagen September 26.

PLATE XX.

THE MILKY WAY IN SCUTUM SOBIESKY PHOTOGRAPHED WITH ORDINARY PORTRAIT LENS BY RORDAME. EXPOSURE 45 MINUTES.



REGION SURROUNDING ALPHA CYGNI. EXPOSURE 1 HOUR 30 MINUTES. ENLARGED FROM PHOTOGRAPH BY RORDAME.

$T = 1911$ Nov. 12.6700 Berlin. M. T.
$\omega = 123° 24'.34$
$\Omega = 35 \ 37 .21$ } 1911.0.
$i = 108 \ 23 .49$
$\log q = 9.88968$

The accompanying diagram, constructed with the aid of these elements, shows that the comet was discovered near its most favorable position for this time of the year, and that it is rapidly moving away from us, although approaching the sun until November 15. During the last half of November and the first half of December it will be too nearly in line with the sun to be visible but southern observers may be able to follow the comet through January and February.

The comet's path makes a very close approach to that of the earth at the descending node and had it come to that point about May 1 instead of December 15 we might have seen a much more conspicuous object.

Ephemeris of Comet *f* 1911 (Quenisset.)

Berlin Midnight	α h	m	s	δ °	′	log *r*	log Δ	Mag.
Oct. 24	15	41	55	+21	54	9.9344	0.1005	6.8
28	15	43	35	+17	28	9.9189	0.1245	6.9
Nov. 1	15	44	44	+13	26	9.9061	0.1469	6.9
5	15	45	30	+ 9	42	9.8966	0.1674	7.0
9	15	46	3	+ 6	12	9.8911	0.1858	7.0
13	15	46	19	+ 2	54	9.8898	0.2020	7.1
17	15	46	30	− 0	14	9.8929	0.2159	7.2
21	15	46	38	− 3	14	9.9001	0.2276	7.3
25	15	46	46	− 6	09	9.9111	0.2373	7.4
29	15	46	54	− 8	58	9.9251	0.2449	7.5

New Comet *g* 1911 (Beljawsky.)—A cablegram from Kiel, Germany, received by telegram from Harvard College Observatory September 30, announced the discovery of a new comet by Beljawsky in Russia on the morning of September 29, the position being given as

Sept. 28.625 Gr. m. t. $\alpha\ 10^h\ 43^m$ $\delta + 8°\ 15'$

The comet was described as visible to the naked eye and moving eastward.

As will be seen by the communications given in another department, the comet was discovered independently by no less than five Americans:

By Professor Joel Stebbins, Urbana, Ill., Sept. 30, 4:48 A.M.

By Mr. W. H. Davis, Winter Haven, Florida, Oct. 1 4:30 A. M.

By Mr. Weston Wetherbee, Albion, N. Y., Oct. 3, 4:45 A. M.

By Mr. Wm. M. Hilton, Monongahela, Pa., Oct. 3, 4:45 A. M.

By three students of Professor D. A. Lehman, Goshen, Ind., Oct. 4, 4 A.M.

Only a few accurate positions of the comet have come to hand, the rapid eastward motion having carried it in so close to the sun in a few days that the light of dawn made observations very difficult.

The following, however, will enable computers to obtain a preliminary orbit:

Date 1911	Local mean time h m	Place	App. α h m s	App. δ ° ′ ″	Observer
Sept. 29	16 30.2	Simeis (?)	10 52 08.1	+ 8 53 58	Photograph by Beljawski
	17 12.7	Copenhagen	10 52 59.8	+ 8 57 49	Strömgren
	16 48.7	Algiers	10 53 09.5	+ 8 58 10	Rambaud
	16 39.1	Williams Bay	10 55 33.7	+ 9 09 14	Photograph by Barnard
30	16 43.3	Algiers	11 03 11.1	+ 9 41 23	Rambaud
	16 55.7	Washington	11 05 46.1	+ 9 50 58	Epps
Oct. 1	16 43.9	Utrecht	11 14 07.5	+10 21 48	Nijland
2	17 17.6	Uccle	11 25 59.9	+10 59 40	Van Biesbroeck
4	17 17.9	Copenhagen	11 50 45.7	+11 55 57	Strömgren

Unfortunately here at Northfield the weather has been cloudy most of the nights of October and so we have had no glimpse of this comet up to the time of this writing (Oct 20).

According to the *Harvard Bulletin* No. 468, the comet as observed at Yerkes Observatory on the morning of September 30 was as bright as a star of the first magnitude and the tail was five or six degrees long. "Frost and Parkhurst observing with a direct vision spectroscope on the 12-inch telescope,

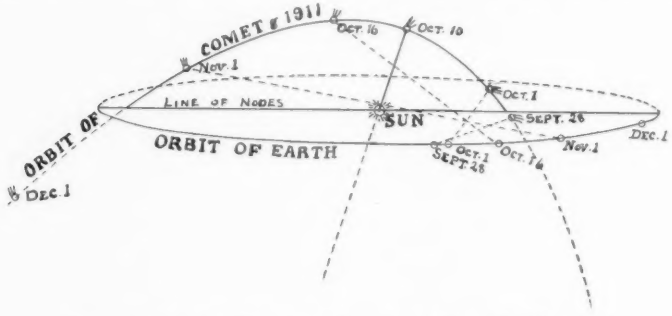


DIAGRAM OF THE ORBIT OF COMET *g* 1911 (BELJAWSKY.)

found the cometary bands very bright in the green and yellow. With a grating spectroscope little continuous spectrum visible; with low dispersion spectroscope continuous spectrum conspicuous from the head, with faint knots in greenish yellow. Professor Barnard secured four photographs with the ten-inch and 6-inch lenses of the Bruce telescopes. These showed a beautiful structure of envelopes, expanding into a fan-shaped tail."

Bulletin 471 states that "two sets of photographs of Beljawsky's comet were obtained by Professor Barnard on the morning of October 4. The comet was many times fainter and the head had greatly changed. The main tail, convex toward north and about 8° long on the negative, consists of many broken streamers and strands. A ray shoots out toward the south at an angle of about 60° with the main tail."

Elements and Ephemeris of Comet *g* 1911 (Beljawsky.)—The following elements and ephemeris appear in *A. N.* 4529. They are based upon observations at Algiers September 29, Uccle October 1 and Copenhagen October 3. They indicate that the comet passed perihelion October 10 and should be visible in the west in the evening during the latter half of October.

PLATE XXI.

COMET BELJAWSKY AND VENUS. OCTOBER 2, 1911, $4^h\ 45^m$ A. M.

OBSERVED BY PROF. LUIS G. LEÓN.

$T = 1911$ Oct. 10.2962 Berlin m.t.
$\omega = 71°\ 38.'90$
$\Omega = 88\ \ 43.\ 54$ 1911.0
$i = 96\ \ 38.\ 16$
$\log q = 9.48230$

Constants for the equator.
$x = [9.07060]\ r \sin (v + 82°\ 32'.65)$
$y = [9.99985]\ r \sin (v + 185\ \ 05\ .28)$
$z = [9.99712]\ r \sin (v + 95\ \ 15\ .50)$

Ephemeris for Berlin Midnight.

1911	True α h m s	True δ ° ′	log r	log Δ	Mag.
Oct. 4	11 47 53	+11 51.5	9.5468	9.9908	2.6
5	12 01 09	12 10.1			
6	14 53	12 19.4	9.5128	9.9865	2.4
7	28 58	12 17.0			
8	43 11	12 02.5	9.4896	9.9874	2.3
9	12 57 22	11 34.7			
10	13 11 16	10 54.5	9.4824	9.9938	2.3
11	24 42	10 01.8			
12	37 33	8 59.1	9.4931	0.0051	2.4
13	13 49 38	7 47.9			
14	14 00 57	6 30.3	9.5190	0.0201	2.6
15	11 26	5 09 1			
16	21 10	3 43.9	9.5545	0.0375	2.6
17	30 10	2 18.8			
18	38 32	+ 0 54.3			
19	46 13	− 0 29.5			
20	14 53 14	− 1 52.5	9.6355	0.0752	3.4

Beljawsky's Comet *g* 1911.—On Friday 29th of September 1911 I received a telegram from Mr. Edward C. Pickering, Director of Harvard College Observatory, saying that a new comet, visible to the naked eye, had been discovered, on the 28th, by Mr. Beljawsky. The comet was in the constellation *Leo Major* and was moving eastward.

Saturday morning was cloudy in the Valley of Mexico, but Sunday morning (October 1st) was very fine. and as soon as I opened the window of my Observatory I saw the comet exactly on the same line of planet Venus. The nucleus was very bright, between the second and third magnitude; the tail was a little inclined to the north (about 75 degrees) and its length was ten degrees, I believe. Exactly on a vertical line through the comet was the star *Regulus* alpha *Leonis Majoris*.

The comet was plainly visible notwithstanding the electric light of the city.

A little before five o'clock the morning light began to appear and a quarter past five the comet was still visible with opera glass.

On Monday I again saw Beljawsky's comet, but as it moved rapidly eastward, it rose much later than Venus.

The observation was not as fine as the day before, on account of some fog; but nevertheless the comet was a conspicuous object in the eastern sky.

This was the last time I saw the comet, but my friend Mr. Jesús Medina, from Puebla, saw it near *Denébola*, "beta" *Leonis Majoris*, on the morning of October 4th. This was the last observation.

We hope that after conjunction the comet will appear in the western sky, as bright or brighter than before.

Beljawsky's is the seventh comet discovered in this year, and number 52 of those discovered in the twentieth century.

PROF. LUIS G. LEÓN.

Mexico City, October 8, 1911.

Ephemeris of Comet *g* 1911 (Beljawsky.)

Berlin	α h m s	δ ° ′	log *r*	log Δ	Mag.
Oct. 24	15 17 16	− 6 56.7	9.7130	0.1128	4.0
28	15 36 13	−11 17.6	9.7812	0.1482	4.5
Nov. 1	15 51 55	−14 58.8	9.8403	0.1809	5.0
5	16 5 26	−18 07.7	9.8917	0.2107	5.4
9	16 17 23	−20 50.0	9.9367	0.2380	5.8
13	16 28 19	−23 11.4	9.9767	0.2627	6.1
17	16 38 18	−25 15.2	0.0125	0.2854	6.4
21	16 47 42	−27 05:2	0.0449	0.3062	6.7
25	16 56 36	−28 40.5	0.0743	0.3259	6.9
29	17 05 09	−30 12.9	0.1014	0.3425	7.2

Comet 1905 II (Borrelly).—A finding ephemeris for this periodic comet was given by G. Fayet in *A. N.* 4523, which arrived just after the October number of POPULAR ASTRONOMY had gone to press. The comet was found close to the ephemeris place, the corrections being + 1ᵐ 49ˢ and +23′, so that the elements there given will need only small corrections.

Date of osculation 1911 Oct. 30.0 Paris m.t.

$M = 352° 56′ 42″.3$
$\pi = 69 12 19 .2$
$\Omega = 76 50 28 .5$ } 1911.0
$i = 30 26 28 .4$
$\phi = 37 53 11 .9$
$\mu = 512″.039$

Date of Perihelion Passage 1911 Dec. 18.601

The following approximate ephemeris shows that the comet will come north this month and will be brightest in December, but may be followed through the winter months:

Date 1911	R. A. h m	Decl. ° ′	log *r*	log Δ	1 : $r^2\Delta^2$
Oct. 30	3 45	− 32 48	0.1784	9.8267	0.977
Nov. 19	3 16	− 23 42	0.1486	9.7424	1.578
Dec. 9	2 49	− 4 59	0.1482	9.7121	1.903
29	2 40	+ 16 19	0.1486	9.7687	1.464
1912					
Jan. 18	2 56	+ 32 18	0.1601	9.8731	0.857
Feb. 7	3 33	+ 42 37	0.1805	9.9806	0.476
27	4 27	+ 48 44	0.2068	0.0767	0.271
Mar. 18	5 34	+ 51 34	0.2365	0.1609	0.160
Apr. 7	6 43	+ 51 39	0.2671	0.2350	0.099
27	7 49	+ 49 36	0.2975	0.3012	0.064
May 17	8 47	+ 46 7	0.3268	0.3603	0.042

Elements of Comet *b* 1911 (Kiess).—In *A. N.* 4552 Dr. F. W. Risten-part gives the following elements of comet *b* 1911, which he compares with those of the comet 1790 I. The dates of observation were July 8, 23 and August 5.

	Comet *b* 1911	Comet 1790 I.
T	= 1911 June 30.2728 Gr. m. t.	1790 Jan. 16.79039
ω	= 110° 34′ 23″.3 } 1911.0	114° 25′ 17″
Ω	= 157 26 21. 7 } 1911.0	172 50 2
i	= 148 28 23. 6 } 1911.0	150 15 53
log q	= 9.835736	9.873516

The middle place is represented by the parabolic elements within $\Delta\lambda = -11″.8$ and $\Delta\beta = +6″.0$. These errors are too small to indicate with certainty a deviation from the parabola and hence do not prove the identity of Kiess' comet with that of 1790.

Ephemeris of Comet 1911 *b* (Kiess.)

[From *A. N.* 4258.]

1911	α h	α m	α s	δ °	δ ′	log *r*	log Δ	Mag. m
Nov. 1	18	25	57	−41	31.2	0 3524	0.4156	11.3
2		26	45	41	29.6			
3		27	32	41	28.2			
4		28	20	41	26.7			
5		29	9	41	25.4	0.3627	0.4343	11.4
6		29	58	41	24.1			
7		30	48	41	22.9			
8		31	37	41	21.7			
9		32	28	41	20.5	0.3727	0.4518	11.6
10		33	18	41	19.5			
11		34	10	41	18.4			
12		35	1	41	17.4			
13		35	53	41	16.5	0.3824	0.4682	11.7
14		36	45	41	15.6			
15		37	37	41	14.8			
16		38	30	41	13.9			
17		39	23	41	13.2	0.3918	0.4834	11.8
18		40	17	41	12.5			
19		41	11	41	11.8			
20		42	4	41	11.2			
21	18	42	58	−41	10.6	0.4009	0.4976	11.9

A. KOBOLD.

Brooks' Comet *c* 1911.—The comet has been quite conspicuous in the northwestern sky in the evening and is now (October 17) equal to a star of the second magnitude in the eastern sky in the morning. It will be visible at least to southern observers through the first half of November.

Ephemeris of Comet *c* 1911 (Brooks.)

[From *A. N.* 4258.]

	α h	α m	α s	δ °	δ ′	log *r*	log Δ	Mag. m
Oct. 31	12	33	56	+ 0	24.0	9.6978	9.9587	3.2
Nov. 1		34	37	− 0	58.8			
2		35	30	2	20.0			
3		36	33	3	39.5			
4		37	46	4	57.2	9.7204	9.9938	3.5
5		39	8	6	12.9			
6		40	37	7	26.8			
7		42	13	8	38.8			
8		43	56	9	48.9	9.7534	0.0263	3.9
9		45	44	10	57.0			
10		47	38	12	3.3			
11		49	36	13	7.8			
12		51	39	14	10.4	9.7918	0.0558	4.2
13		53	44	15	11.2			
14		55	53	16	10.3			
15	12	58	4	17	7.8			
16	13	0	17	18	3.6	9.8317	0.0824	4.5
17		2	32	18	57.8			
18		4	48	19	50.4			
19		7	5	20	41.7			
20	13	9	23	−21	31.7	9.8709	0.1063	4.9

M. EBELL.

Observing Halley's Comet from the Summit of Mount Whitney.—In the *Publications of the Astronomical Society of the Pacific* for October 1911 Dr. Aitken refers to the fact that Mr. G. F. Marsh, of Lone Pine, at the foot of Mt. Whitney, made the ascent of the mountain for the purpose of viewing from its summit Halley's comet and the total eclipse of the Moon on May 23, 1910. Dr. Aitken says "so far as I am aware, Mt. Whitney is by far the highest point on the earth's surface to which any one has climbed for the sake of seeing a comet, and a record of the fact seems of interest."

The following extract from a letter from Mr. Marsh to Dr. Aitken will be of interest to our readers. After describing the difficulties of the day and a half journey Mr. Marsh says: "I made good time and got to the top of Mt. Whitney [14,500 feet] at about 11 a. m., just the time I thought I would. I found the building in good shape and everything as I had left it. I made a fire, but did not feel hungry. I fixed my signal and waited till 11:45, the time I was to signal to my wife. I opened the shutter and immediately got a flash from Lone Pine. Then I gave my signal —1.2— and got 1.2 in return. I also got signals from several parts of town, showing that they were on the lookout for me, as a few said I would never get there.

"I fixed up good for the night, read the weather report of 23 below zero, and fixed up a signal fire of old paper and chips so I could signal at night, but it started to cloud up and looked like storming. Heavy banks of haze formed to the west and at sundown the whole sky was cloudy and I thought it was all off. At 7:30 p. m. it cleared and I lit my fire. Clouds drifted across but I got an answer from Lone Pine.

"I was getting anxious about the moon and the comet when the clouds began to break. I commenced to look for the comet but the clouds bothered. Pretty soon the cloud raised and I saw the moon about half covered, and in watching it so close I almost forgot the comet. I watched the Moon until it was almost covered, then I saw the tail of the comet. Then all of a sudden the comet showed in plain view. The cloud had passed by and the moon was dark. The comet was further west than I expected. It was a good deal larger than I expected and of a milky color, but quite bright and the tail streamed out for a long distance and was very beautiful. It seemed like a great horse's tail streaming out. The comet seemed to travel very fast. In my excitement I forgot all about the time, but was wishing all the time I had someone with me who understood more about it. It was a beautiful sight, The sky up high was perfectly clear, but low down great banks of fog were rolling. I watched the comet until it dove into the fog bank to the west and was gone, but the tail shone out for quite a while."

Numbering of Recently Discovered Asteroids.—In *A.N.* 4521 permanent numbers are assigned to 23 minor planets for which satisfactory orbits have been determined during the present year. The total number now becomes 714. Each year the difficulty of keeping track of this great number of little planets, increases and many of the old ones are rediscovered and given provisional designation as new objects, only to be identified with those already known as soon as their orbits are computed. Eighteen of those discovered during the past year and supposed to be new were thus identified. The following is the list recently numbered:

No.	Name	Provisional Designation	Discoverer	Place	Date of Discovery
(692)		1901 HD	Wolf-Kopff	Königstuhl	1901 Nov. 5
(693)		1909 HN	Kopff	"	1909 Sept.21
(694)	Ekard	1909 JA.	Lorenz	"	Nov. 9
(695)		1909 JB	Metcalf	Taunton	Nov. 7
(696)	Leonora	1910 JJ	Metcalf	"	1910 Jan. 10
(697)		1910 JO	Helffrich	Königstuhl	Feb. 14
(698)		1910 JX	Helffrich	"	Mar. 5
(699)		1910 KD	Helffrich	"	June 5
(700)		1910 KE	Helffrich	"	June 5
(701)		1910 KN	Helffrich	"	July 12
(702)		1910 KQ	Helffrich	"	July 16
(703)		1910 KT	Palisa	Vienna	Oct. 3
(704)	Interamnia	1910 KU	Cerulli	Teramo	Oct. 2
(705)		1910 KV	Ernst	Königstuhl	Oct. 6
(706)		1910 KX	Helffrich	"	Oct. 9
(707)		1910 LD	Wolf	"	Dec. 22
(708)		1911 LJ	Helffrich	"	1911 Feb. 3
(709)		1911 LK	Helffrich	"	Feb. 3
(710)		1911 LM	Palisa	Vienna	Feb. 28
(711)		1911 LN	Palisa	Vienna	Mar. 1
(712)		1911 LO	Wolf	Königstuhl	Mar.19
(713)		1911 LS	Helffrich	"	Apr. 18
(714)		1911 LW	Helffrich	"	May 18

The table of elements of the above minor planets is given in *A. N.* 4521.

COMMUNICATIONS QUESTIONS AND ANSWERS.

[This department is designed especially for the use of amateurs. Beginners are invited to send in their puzzling questions. The editors will try to see that answers are given to reasonable questions but will not hold themselves responsible for the correctness of the views expressed in the communications which may find place here. All communications should be brief.]

Independent Discovery of Comet *g* 1911.—At the request of Professor Berlin H. Wright, of DeLand, Fla. I write you that at 4:30 A.M. October 1, I discovered a bright comet with a tail 10° or 12° long about 12° or 15° distant and a little to the E. of N. of Venus. I first saw it with the unaided eye and then used my field-glass. In a few minutes it was obscured by invisible haze (and daylight) that permitted small stars to be seen by aid of the glass. I live about 200 feet distant from the W. shore of a small lake of about a mile wide.

On the morning of October 2 I watched it come up, but before it had gotten fairly above the haze of the horizon and I had a good look at it—it was again obscured. On October 3, I did not look for it. On October 4 it was hidden before I got up at 4:30.

A gentleman told me on the third ins't that he had observed it but did not give me the date.

As near as I could mark it on Professor Wrights small chart from my short observation with a field glass, on October 2, it was R.A. 12^h + Dec. about +8°.

Thus far I have no account of it.

Hoping this may have been the first observation of a new comet.

W. H. Davis.

Winterhaven, Florida, Oct. 4, 1911.

Independent Discovery of Comet *g* 1911.—This morning at 4 o'clock three of my students saw a comet about 12° above the horizon and about 4° north of the east point, with a tail of 2° or 3°, extending westward, as it should. It is a new one, or what is its name, etc.

D. A. LEHMAN.

Goshen College, Goshen, Ind. Oct. 4, 1911.

Independent Discovery of Comet *g* 1911.—While observing the sky this morning at about 4:45 I saw a large and beautiful comet in the constellation of Leo. Its position was approximately, 11 hours 25 minutes right ascension, and some 11 degrees north declination. Has this comet been seen before and who was its discoverer? The heavens were wonderfully clear to the horizon. Brooks' new comet, also the one just discovered by Quenisset, (now in Draco) was easily seen.

WESTON WETHERBEE.

Albion, N. Y. Oct. 3, 1911.

Independent Discovery of Comet *g* 1911.—I have mailed you under separate cover copies of the "Monongahela Republican" and "Pittsburgh Dispatch" in which are marked articles descriptive of the discovery in this country of the latest or "Hilton's Comet."

WM. M. HILTON.

Monongahela, Pa., Oct. 7, 1911.

The newspaper reports referred to state that the new comet was discovered by Mr. Hilton at 4:45 on Tuesday morning October 3. "At the time of its discovery it was about fifteen degrees above the horizon, directly in the east in the constellation Virgo. Its head was bright and it had a well-defined tail several degrees in length. The tail extended toward the zenith."[ED.]

Quenisset's Comet; Brooks' Comet; Sunspot, etc.—Quenisset's Comet, (1911 *f*), was first sighted here on the evening of 1911, October 4, clouds having prevented an earlier view. Inasmuch as I had no ephemeris which was reasonably in date at the time, I was compelled to extend a search for the comet, but succeeded in locating it in the field of my 3-inch refractor, after a sweep of a few moments. The approximate position of the object at Oct. $4^d\ 7^h\ 55^m$, C. S. T., as determined from the circles on the equatorial was

$$\alpha = 15^h\ 23^m; \qquad \delta = +\ 51°\ 5'.$$

On account of the moon, the body was rather difficult to study, but for the most it appeared simple, circular in outline, with a somewhat brighter center, and could have not been much over 45 seconds or 1 minute in angular diameter. According to my estimate I placed its brightness as equivalent to about mag. 8, but this may be somewhat in error on account of the obliterating effect of the light of the moon on faint objects. Dnring the observation it was thought that a little motion toward the E. could be detected, with respect to a comparison star nearby. Another observation of comet *f* was made on the next clear night, October 7, but nothing new was noticed, and the moon was very bright; comet near a small star.

Brooks' comet has been kept under observation by the writer on nearly every clear evening since 1911, July 25. The observation made on August 8, was marked especially by a telescopic meteor that was seen to traverse the

very field of comet, (8^h 43^m, C. S. T.). On August 18, this comet was at the verge of visibility with the naked eye, and on the following night, (August 19), was unmistakable. Brooks' comet is now distinctly visible to the unaided eye, even in strong twilight. On October 4 it was a short distance S. W. of η Ursae Majoris; viewed through the telescope, the nucleus was found to be well defined, though not stellar, and slightly yellowish in color. The tail could not be traced very far on account of proximity to the horizon, but it must have been several degrees in length, because it is easily perceptible in an opera-glass, and almost as easy to unaided vision. The view of comet *c* on this evening brought to my mind the appearance of Halley's comet soon after the latter became within reach of the naked eye.

I wish to recall an observation of a "polar sunspot," published in the December, 1910, issue of this journal, p. 644. The position of the spot I described in that note is unquestionably erroneous, and the letter should have never been submitted or printed. At the time of this observation I was very inexperienced, and, because I *did see* a spot at the *top* of the solar *disc*, I took it to be in latitude almost S. 90°, a location in which spots never appear; this explains my mistaken position ascribed to the spot. I greatly regret my misdoing in presenting such a record, and I sincerely trust that the error will now be correctly understood and overlooked.

It may be of interest to my readers to know that the society for Practical Astronomy has now a membership exceeding the number of forty persons. Several of these members have been obtained through the kindness of the medium of POPULAR ASTRONOMY.

FREDERICK C. LEONARD.

1338 Madison Park, Chicago.
October 8, 1911.

Genesis and Science.—In the October number of POPULAR ASTRONOMY appears an article by Mr. Frank Gilman on Genesis and Science. This article would not be worth noticing, were it not for the fact that he believes he has completely answered the one in a previous number by Mr. Macpherson.

With this article I have nothing to do, but will try to answer Mr. Gilman in order. In his first paragraph he says "Science knows no such conception as a universal beginning of things including matter." That is true, Science has no conception of such a thing, on the other hand, it has no conception of the eternity of things including matter, nor has it any conception of either infinite space or bounded space. Mr. Gilman also states that the passage in Genesis *i* is wrongly translated, and speaks of perpetuating the pious fraud. There are only seven words in the original, and he himself makes three mistakes in the translation. "In the beginning the Gods created the heaven and the earth." If it is insisted that the plural word *Elohim* should always be translated *Gods*, the proper translation would be: In the beginning *Gods* he created the heavens and the earth; for although the word *Elohim* is plural, the next word translated *created* is in the singular, there is no article before *Elohim*, and the word translated *heaven* is in the plural. He states, moreover, that *The Gods* agrees with another statement of the bible that "There are gods many and lords many." It would be interesting to quote this passage with the context. The apostle is discussing the conscientious scruples, that some Christians had about eating meat that had been offered in sacrifice to idols, in which he says "As concerning the eating of those things that are

offered in sacrifice into idols, we know that an idol is nothing in the world, and there is none other God but one, for though there be that are called gods, whether in heaven or in earth (as there are gods many and lords many). But to us there is but one God, the Father, of whom are all things, and we in him, and one Lord Jesus Christ, by whom are all things, and we by him." The passage that Mr. Gilman quotes is an explanatory clause, and is used with reference to those people, who believe in and offer sacrifice to idols. This statement agrees with another passage, Ephesians IV 5. 6: One Lord, one faith, one baptism, One God and Father, of all who is above all, and through all and in you all. The 26th verse of the first chapter, and the 22nd verse of the 3rd Chapter of Genesis are very peculiar. In the first of these verses *God* is plural, *said* is singular, *us* is plural, *man* is singular, *our* is plural, and *image* is singular, *them* and *have* are both plural, and refer to the singular noun *man*. The 27th verse is even more peculiar. *God* is plural, created is singular, *man* is singular the words *his own image* are all singular and refer to the antecedent *God* which is again plural; *created* is singular, *he* is also singular, both words having reference to *God* which is plural, *him* meaning man is singular, but in the next sentence we read: *Male* and *female created he them*. Here the word *them* is plural and refers to the singular noun *man*.

In the 22nd verse of the 3rd chapter the expression is slightly different, it is not now *Elohim* but *Jehovah Elohim said* which verb is still singular. I will not attempt to discuss any theological dogmas or opinions on these passages, but simply call attention to the fact, that the plural form of the noun has still a singular predicate. it may be a plural personality and one *God*, or more probably a plural of excellence or majesty; most of the best Hebrew scholars at the present day, seem to favor the latter view, and the proper translation is given in the revised version. "In the beginning God created the heavens and the earth." The same singular and plural expression occur with reference to *man*, that is, a single conception with reference to the race, but dual in form.

"The earth was without form and void" clearly means in common parlance, it had no definite geometrical form; *void* seems to mean destitute of life, for I think it inconceivable that the author would state that matter was created and immediately contradicted himself by saying that the earth was destitute of matter. How does Mr. Gilman know that this statement is false and absurd? Again, it is quite unscientific to contradict a direct and positive statement by any hypothesis, however plausible it may seem.

The nebular hypothesis, may or may not be true, it certainly has not been proved by observation, no measures have so far detected any shrinkage of the sun's diameter, or any diminution of its heat, nor any change in individual nebulæ; although the separate nebulae appear in all forms of condensation from vapory matter to the most condensed form, there are however, some grave objections to the nebular hypothesis, and no scientist at the present day believes it in exactly the same form as propounded by Laplace.

The next sentence is unique. "Darkness was upon the face of the deep" The nebular hypothesis is again quoted, *heat* is confounded with *light* and while it is probable that heat could not exist without a certain amount of light, yet it is a well known fact, that the most intense heat rays are in the infra red, or invisible part of the spectrum; and what about clouds?"

Two more sentences are quoted, but as the criticism depends on hypothesis only, it is not necessary to proceed further.

The statement that the Hebrew word *yom* always means a day of twenty-four hours is clearly unscientific, for there is no such natural division of time as an hour, it can only be defined as the $\frac{1}{24}$th part of a day; whatever kind of a day is used, it is also clear, that the word cannot be used in that sense on the first second and third days of creation for it is stated that in the fourth day God created two great lights the sun and the moon to rule the day and the night, and there could be no solar day at least without the sun.

There are also many expressions in which the word certainly has different meanings as for examples, in the following passages.—

"The day that the Lord God made the earth and the heavens."

"The days of the years of my life are one hundred and thirty years."

"The day of vengeance of our God."

"The days of thy mourning shall be ended."

"An acceptable day to the Lord."

"As thy days so shall thy strength be."

"In the day of prosperity be joyful."

"In the day of adversity consider".

These, and many other passages show that the word translated *day* is not always used in the restricted sense which is sometimes ascribed to it. The bible makes no pretense to be a book of systematic science; the great question under consideration, so far, is its truthfulness, which, as far as I know, has not been impeached The last clause, however, quoted from the French writer Guibert can well be conceded, as the Bible has never attempted to make any scientific revelation, but that is entirely a different thing from attempting to prove that the statements in the Bible are unscientific, and will not bear the light of investigation in this twentieth century.

EDGAR FRISBY.

Washington, D. C.

An Open Letter.—Following the open letter of Mr. Frank Gilman, criticising Hector McPherson's recent article, I beg to submit a query.

Why does the capable Editor Wilson lessen the probable value of his October article on "Life in Other Worlds" by an early reference therein to a Deity; in such a manner as might bias the first opinions of the young student, who is today's best hope for exact truth in the future?

While Editor Wilson is most careful and exact in reference to other astronomers, leaving open all doubtful questions; while he rightfully bases his arguments in some instances upon analogy; why does he presuppose a Supreme Being, for "Whom" there seems with each year less *need* in the most exact of sciences?

This is not a criticism of belief, that is one's own business; but why should that belief be presented willy-nilly as a fact to the reader of a scientific journal?

I am confident that a publication of this open letter will gain the approval of the larger half of POPULAR ASTRONOMY's patrons.

FERDINAND GRAHAME.

Erie, Pa.

A Closed Discussion.—The editor does not care to open the columns of POPULAR ASTRONOMY to a theological discussion and so asks that the above communications be allowed to close the discussion of Mr. Macpherson's paper. He agrees with Mr. Macpherson that there is a wonderful similarity between

the Genesis story of creation—a tradition handed down many generations before it was ever written,—and the modern science view of the earth's beginning. He agrees with Mr. Gilman also that religious discussion is not appropriate matter for a scientific magazine. But he does not agree at all with Mr. Ferdinand Grahame that one should not mention the Creator of the Universe as an assured fact rather than an hypothetical being. The rudest go-cart seen on the roadside suggests immediately a maker. Much more does the infinite variety of wonderfully perfect mechanism found throughout the universe compel one to believe in a creator of infinite intelligence and power. He who can believe that all these things came by chance has a tremendous bump of credulity.

Viewing Venus by Daytime.—This has been an unusual day (Oct. 18) as to favorable conditions for viewing Venus with the unaided eye: First, her nearness to the earth causes her to shine with unusual brilliancy as our morning star. A third, and very favorable condition was her position in the heavens, being located about ten degrees almost due south of the moon, making it a comparatively easy matter to put the eye upon her at any moment. Observing these conditions early in the morning, I determined to watch her as long as possible.

Just before nine o'clock I went over to the school building, calling attention of the students to the silver dot in the sky.

It raised quite an excitement, both among the high school students, and those in the grades. Going up town, the business men, and pedestrians became equally as much interested as the students had been. All thought it "so strange to see a star shining brightly in the daytime." The interest was greatly increased when I took my three-inch telescope to the school house, and during the noon hour showed teachers and students the beautiful crescent of Venus, far brighter than the moon, even refusing to be extinguished by the glare of the noon-day sun. I think it safe to say that several hundred people, men, women, and children, were greatly interested in observing the unusual sight, both with the unaided eye, and through the telescope.

M. B. KELLY.

Nortonville, Kan., October 18, 1911.

Question.—Will you kindly let me know where the six largest telescopes in the world are located and also their diameters.

ANSWER.—The following list is taken from Newcomb-Engelmann's *Populäre Astronomie*, 4th edition, page 128.

Refraetors		Aperture	Reflectors	Aperture
Yerkes Observatory		102 cm	Birr Castle (Rosse)	183 cm
Lick	"	91	Mt. Wilson	150
Meudon	"	83	Melbourne	122
Potsdam	"	80	Paris	120
Pulkowa	"	76	Meudon	100
Nice	"	76	Mills (Santiago, Chile)	93

A Brilliant Meteor.—On the sixteenth of September 1911 9.22 P. M. Central Time a brilliant meteor passed over the north eastern sky. The trail was visible for about six seconds after the meteor disappeared.

G. A. DUERLER, JR.

San Antonio, Texas, Sept. 20, 1911.

Question:—Will you kindly explain in a popular way, so that the average intelligent layman can understand, "Michelson's Interferometer."

Michelson's Interferometer.—This interferometer consists of three optically flat glass plates and a traveling carriage for one of them. They are placed as in the diagram. A and B are silvered on the heavily lined side C is half silvered on one side Let a monochromatic beam of light strike the plate C as in the diagram. A portion of it will be reflected up to A and back through C to the eye. The other portion will go through C and be reflected by B and C successively to the eye.

Suppose the total lengths of these two beams are the same. As the light waves in them vibrate synchronously, at the observing eye crest will coincide with crest and trough with trough and we will have light. Now move back plate A on its traveling carriage so that the difference of path of the two beams is one half the wave length of the light used. In this case at the eye the crest of each light wave of one beam will coincide with the trough of a wave in the other beam and vice-versa, the disturbance, of the two trains of light waves counteract each other and we have darkness.

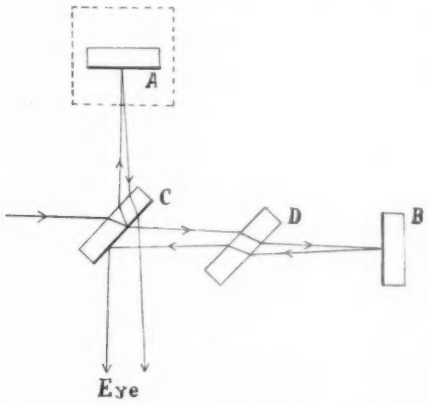


DIAGRAM OF MICHELSON'S INTERFEROMETER

If the path difference now be made one whole wave length we will again have coincidence of crest with crest, trough with trough, and light at the eye; at one and a half wave length's difference, darkness and so on. Thus we can measure the number of wavelengths of a given light equal to the distance the carriage holding C is moved. We can therefore find the length of a wave of light by moving the carriage a known distance, or we can measure this unknown distance in terms of known wave lengths of light.

It is apparent that when the carriage is moved one inch the path difference is changed two inches. An unsilvered plate D similar to C is usually put in the path of the light to B so that each beam will have the same distance in glass to traverse before it reaches the eye. Only the most obvious use of the Michelson interferometer has been given, but if the interference of light is thoroughly understood there will be no difficulty in understanding the instrument.

NOTES FOR OBSERVERS.

A Meteor Section.—Dr. Charles P. Olivier of Science Department of Agnes Scott College, Decatur, Georgia, will undertake the direction of a Meteor Section of the proposed Association of observers. Dr. Olivier is a graduate of the University of Virginia and received his doctor's degree last June, after a post graduate course in Astronomy and Mathematics pursued at the Leander McCormick and Lick Observatories. His thesis was entitled "175 Parabolic Orbits and other results deduced from over 6200 Meteors." Having observed this large number of meteors himself, Dr. Olivier is well-fitted to give practical advice to those who wish to begin the fascinating study of these mysterious objects.

All who would like to join in systematic observation of meteors are urged to write to Dr. Olivier and enroll as members of the Meteor Section.

The Variable Star Association.—In response to the Editor's suggestion under "Notes for Observers" in the October issue, that the variable star observers in this country organize a section or association for the furtherance of the work by coöperation, and for the mutual encouragement and benefit to be derived from such an association, I would report that progress is being made toward the end, and there is every prospect that by next month we can submit several lists of observations made by members of such an association. It is suggested that the title of this organization be "The American Association of Variable Star Observers."

To further the matter, a preliminary publication should be made of the stars being observed by each member coöperating in this plan. Thus each member will know at the outset who besides himself are observing certain stars on his individual list, and if he has occasion to correspond respecting certain observations, he will know at once whom to address in each case.

The further suggestion is made that each member of the association send in his list to the writer by the tenth of the month, in order that the report may reach the editor of POPULAR ASTRONOMY in time for publication each month.

The lists should contain first, the name and address of the observer; second, the type and diameter of aperture of the instrument used: then the name of the star, the date of observation and the estimate of its magnitude. As these lists of observations are published solely for purposes of comparison, it will not be necessary to include in the lists observations of stars that are invisible at the time in the glass used, where the observation is expressed as less than ($<$) the magnitude of the faintest star visible in the field.

In compliance with this plan the writer herewith submits the list of variable stars which he is observing, and his observations from September 10th to October 10th.

As fast as lists are sent to the corresponding secretary, they will be forwarded to the editor of POPULAR ASTRONOMY for publication, and soon we hope to have such complete sets of observations that a comparison of estimates will in each case be a source of pleasure and profit to all participants in this plan.

All interested in this subject are urged to bring the matter to the attention of any others who might in their judgment coöperate with us.

It is very much desired that members of the Cincinnati, Dayton and Pittsburg Astronomical Societies, who are interested in the observation of

variables, will give this matter their consideration, and join our association.

The following is the list of those who have already signified the desire to coöperate with us in this work:

Dr. Edward Gray, Eldridge, Cal., Mr. R. E. Fosdick, Dayton, Ohio, Mr. S. C. Hunter, New Rochelle, N. Y., Mr. H. W. Vrooman, Kokomo, Ind. Mr. A. E. Pulford, Trinity College, Hartford, Conn., Professor Anne S. Young, Director Mt. Holyoke Observatory, South Hadley, Mass.

It may be added that all observations made by members of the Association will be sent each month to Professor E. C. Pickering, Director of the Harvard College Observatory, who provides the necessary charts, and publishes from time to time discussions of the observations.

The writer takes the opportunity of thanking the Editor of POPULAR ASTRONOMY and Professor Pickering for the interest they have taken in this plan to organize an association of variable star observers, and if the monthly reports of this Association should prove of any interest to the readers of POPULAR ASTRONOMY, and of value to the Association, he will be amply repaid for his efforts to popularize variable star observing.

WILLIAM TYLER OLCOTT.
Corresponding Sec'y.

List of Long period variable stars being observed by W. T. Olcott, Norwich, Conn.

X, T, RW, V, RR and ST Andromedae, V and W Cassiopeiae, R Can. Ven. R and S Piscium, T Cephei, R Arietis, *o* Ceti, W Persei and W Aurigae, W Tauri, R Scuti, R, V and X Camelopardalis, U and S Lyncis, R, T and S Aquarii, R, S and U Canis Minoris, R Pegasi, U Geminorum, R Corvi, R, T and V Cancri, R, RT, U, SS and χ Cygni, S, T and RT Hydrae, W Lyrae, R Sagittarii, R Leonis, R Leonis Minoris, R Vulpeculae, R, S and T Ursae Majoris, R and S Coronae, R and S Bootis, U Serpentis, R Draconis, R Delphini, R Comae Ber, RU, U, S, RV and T Herculis, R and Z Ophiuchi, RS, RU and S Librae, R and U Virginis.

Variable Star Observations Sept. 10th to Oct. 10th 1911.
W. T. OLCOTT, Norwich, Conn. 3″ Refractor.

Star	Date Sept.	Estimate m	Star	Date Sept.	Estimate m
T Cephei	12	6.0	T Herculis	12	10.5
	28	6.2		26	9.2
RCoronae	12	9.6	S Coronae	13	10.4
	26	11.0	Z Ophiuchi	13	9.2
RV Herculis	12	10.5		23	9.4
R Draconis	12	8.6	W Persei	13	9.0
	26	9.3	R Scuti	14	5.2
ST Andromeae	12	9.5	T Aquarii	14	10.7
	22	9.6	R Aquari	14	9.0
V Andromedae	12	9.4	R Arietis	14	8.7
	22	9 6		23	9.2
	26	9.5	R Camelopard	26	9.8
R Delphini	12	10.1	R Cygni	26	11.0
R Pegasi	23	9.0			
	12	9.5	χ Cygni	26	5.5
W Lyrae	12	10.5			
	26	9.2			

PROFESSOR ANNE S. YOUNG, Mount Holyoke, Mass.

			m				m
T Andromedae	Oct.	7	11.8?	S Urs. Maj.	Oct.	10	8.0
T Cassiopeiae	"	7	9.6	U Herculis	"	10	10.9
S Piscium	Sept.	18	11.9	W Herculis	"	10	8.3
X Cassiopeiae	Oct.	7	9.8	R Draconis	"	10	10.2
R Triang.	"	10	5.9Finder	W Lyrae	"	9	8.7
R Persei	"	7	8.6	S Delphini	"	9	9.9
R Aurigae	"	7	8.8	RZ Cygni	"	9	11.9
S Aurigae	"	7	8.9	X Cephei	Sept.	26	12.3
S Camelop	"	7	9.8	SS Cygni	Oct.	9	11.7
Z Aurigae	"	7	10.5	RT Pegasi	"	9	9.6
R Lyncis	"	10	11.8	S Lacertae	Sept.	23	8.2
R Urs. Maj.	"	10	10.7	R Lacertae	"	26	8.9
R Cor. Bor.	"	10	10.7	R Pegasi	Oct.	9	8.4
T Urs. Maj.	Sept.	19	10.3				

GENERAL NOTES.

Rev. Joel H. Metcalf has moved his observatory to Winchester, Mass., eight miles from Boston and expects to renew his work of photographing asteroids there. He asks the coöperation of some observatory, having an equatorial telescope large enough to follow the faint asteroids which he discovers, in securing sufficient observations to determine their orbits accurately.

Professor R. H. Tucker, Astronomer at the Lick Observatory, has returned to Mt. Hamilton after three years leave of absence. He has been in charge of an astronomical expedition to San Luis, Argentina, under the auspices of the Carnegie Institution, to determine accurate positions of the southern stars.

Professor R. T. Crawford of the Berkeley Astronomical Department, University of California, is absent on leave during the academic year and is at present at Berlin. He was delegated to represent the University of California at the recent Jubilee of the University of Breslau (Pub. A.S.P. Oct. 1911).

Professor D. W. Morehouse, of Drake University, has been appointed Instructor in Astronomy at Berkeley during Professor Crawford's absence. In addition to his duties as instructor he is engaged in graduate study. (Pub. A. S. P. Oct. 1911).

Mr. Eli S. Haynes, who has been in charge of the Laws Observatory at the University of Missouri, has been appointed a university Fellow in Astronomy at Berkeley and is also engaged in graduate study (Pub. A. S. P. October 1911.)

Mr. R. K. Young and Paul W. Merrill, Fellows in the Lick Observatory, are spending this year in graduate study at Berkeley.

Astronomical and Astrophysical Society of America.—There follows a list of the extra papers added to the program of the Ottawa meeting of the A. A. S. A. after the announcement of the meeting had been sent out.

E. E. BARNARD. Preliminary report on the negatives of Halley's comet taken by Mr. Ellerman at Honolulu.

FREDERICK SLOCUM. The Solar Prominence of October 10, 1910.

OLIVER J. LEE. Vapor-density effects on the calcium lines, H, K and g.

EDWIN B. FROST. Radial Velocity of Halley's Comet as derived from a Spectrogram.

S. I. BAILEY.—Note on the Magnitudes of the Stars in Messier 3.

S. ALBRECHT. Tables of Effective Wave-lengths of Lines in Stellar Spectra.

S. ALBRECHT. Wave lengths of the Silicon Lines in λs4552.7, 4567.9 and 4574.9 in Stellar Spectra and in Laboratory Spectra.

S. ALBRECHT. On Fundamental Systems of Wave-lengths in Stellar Spectra, especially for the B-Type Stars.

H. N. RUSSELL. Photographic Determination of the Position of the Moon.

A. E. DOUGLASS. Note on the Ellicot Astronomical Instruments.

R. H. CURTISS.
Editor and Acting Secretary.

Ann Arbor, Mich.,
Sept. 21, 1911.

New Double Star.—The following new double star found and measured with my 6½-inch Clark refractor is reported for record.

ρ 75 B.D. + 15° 2906
$15^h\ 40^m\ 13^s$, 15° 35′ (1910)
(9^m, $9^m.8$) Found 20 May, 1911.

	°	″
1911.383	325.5	6.06
.388	.8	.09
.466	.3	.02
1911.412	325.5	6.06

ρ 73 is S. D. −5° 3329, ($9^m.5$)

Professor Fox has kindly measured this pair and made,

	°	″	
1911.451	359.0	3.40	
.448	360.5	3.38	
.462	357.9	3.55	$9^m.8$—$10^m.2$
1911.454	359.1	3.44	

E. D. ROE, JR.

Syracuse University, Sept. 27, 1911.

Astronomical Fellowship of the Nantucket Maria Mitchell Association.—The following circular issued by the Nantucket Maria Mitchell Association shows that the foundation of an astronomical fellowship has become an accomplished fact. Here is a splendid opportunity for some young woman who has the required qualifications. That the work during half of each year is to be at one of the larger observatories and that every fourth year the fellowship is to be available during the entire year at one of the larger observatories in Europe or America are unique features of this fellowship. There should be no lack of applicants.

The Nantucket Observatory is equipped with a five-inch Alvan Clark telescope, and a micrometer for measuring Stellar Spectra.

The Nantucket Maria Mitchell Association offers an Astronomical Fellowship of One Thousand Dollars, to a woman, for the year beginning June 15, 1912, under the following conditions:

The year shall be divided into two periods, approximately as follows:

June fifteenth to December fifteenth on Nantucket. This period shall be occupied in observation, research or study, and in lectures or instruction to classes or individuals.

February first to June fifteenth at one of the larger observatories. This semester shall be occupied in original research and study. During this period a distinct plan for the following Nantucket period shall be formulated.

Every fourth year the fellowship shall be available during the entire year for study at one of the larger observatories in Europe or America.

The fellowship will be awarded annually, but in order that the work at Nantucket may be combined advantageously with the work at the selected observatory, the preference will be given to the same candidate for three successive years. This candidate shall have first consideration among applicants for the special Quadrennial appointment.

A competitive examination will not be held. The candidate must present evidence of qualifications under the following heads:

1. A letter from the candidate addressed to the Secretary of the Committee, giving an account of previous educational opportunities and training, and of plans for future work.

2. College diploma or certificate from the registrar of her college, and if she has already held a position as instructor or teacher in any college or other institution, a clear statement of the work done, together with a certificate as to the quality of work.

3. Examples of work already accomplished.

4. Testimonials as to ability and character.

5. Satisfactory evidence of thoroughly good health.

The fellowship at all times must be used for purposes of serious study, and the fellow should be as free as possible from other responsibilities.

The Committee reserves the right to withhold the Award of the Fellowship in case the work presented to the examiners should not in their judgment be of sufficient merit to deserve the award.

Application for the year beginning June 15, 1912, should be made under the above heads, and must be in the hands of the Secretary of the Committee, Mrs. Charles S. Hinchman, 3635 Chestnut Street, Philadelphia, Pennsylvania, on or before March 1, 1912.

COMMITTEE
PROF. MARY W. WHITNEY, Director of Vassar College Observatory, *Chairman*
ANNIE J. CANNON, A.M., Harvard Observatory, *Vice-Chairman*
PROF. ANNE S. YOUNG, PH. D., Mt. Holyoke Observatory
DR. EDWARD C. PICKERING, Director of Harvard Observatory
ELIZABETH R. COFFIN, A. B., Vassar College, 1870
FLORENCE M. CUSHING, A. B., Vassar College, 1874
LYDIA S. HINCHMAN, Philadelphia
SECRETARY.

A Very Bright Meteor.—While photographing a region in Hercules on Saturday evening September 16, 1911, I noticed a most brilliant meteor in the western sky. My attention was attracted from guiding by a very

bright flash of light such as would be expected from vivid lightning. I looked up at once and saw the huge bright object moving very rapidly toward the western horizon leaving a very luminous trail. The bright nucleus vanished after moving fifteen or twenty degrees, but the trail of light could be seen with the naked eye for fully five minutes. It soon assumed the form of the letter "C" with the opening toward the horizon. The meteor appeared at 8.15 C. S. T., a short distance south of the line joining Arcturus and Vega, about three times as far from Arcturus as from Vega. Its position roughly was 17^h in R.A. and $+30°$ in declination.

C. H. GINGRICH.

Yerkes Observatory, Williams Bay, Wis.

The Albedo of Clouds.—The albedo of clouds varies between wide limits, but was formerly assumed to average about 0.75; i.e., the upper surface of the clouds was supposed to reflect about 75 percent of the incident sunlight. The albedo of white paper is 0.70; of new-fallen snow 0.78. The first attempts to measure accurately the albedo of a layer of clouds seen beneath an observer posted on the top of a mountain were those made by Abbot and Fowle on Mount Wilson in 1906, and gave an average of 0.65, but this result was later found to be doubtful, owing to errors in reduction. Within the past few months this problem, which has such important bearing upon the physics of the earth's atmosphere, has been taken up in Germany by Messrs. Stuchtey and Wegener, who made numerous measurements with a specially constructed albedometer in the course of several balloon voyages. They found the following values, which have been corrected by eliminating the general radiation of the sky, and refer only to the proportion of direct sunlight reflected: Lower stratus clouds, 0.54; higher stratus, 0.76; cumulus, 0.67. They also measured the albedo of the earth's surface as seen from altitudes between 600 and 1650 meters. The albedo of open fields was found to average 0.15; of woods, 0.06. (*Scientific American*, July 22, 1911).

Abstracts of Papers presented at the Ottawa meeting of the American Astronomical and Astrophysical Society.

THE SPECTRA OF 762 DOUBLE STARS.

BY ANNIE J. CANNON.

A list was prepared of all stars in the "General Catalogue of Double Stars" by Burnham, and the reference Catalogue of Southern Double Stars by Innes, in which the components are of magnitude 7.5 or brighter. A special examination of the Harvard photographs was made to determine the spectra of these stars.

CLASSIFICATION OF SOME STELLAR SPECTRA PHOTOGRAPHED WITH THE SLIT SPECTROSCOPE AT THE ALLEGHENY, LICK AND YERKES OBSERVATORIES, COMPARED WITH THOSE TAKEN AT HARVARD WITH THE OBJECTIVE PRISM.

BY ANNIE J. CANNON.

The Draper classification of stellar spectra depends wholly on photographs taken with the objective prism. In view of the large number of photographs being taken with the slit spectroscope at various other observatories, it appears to be a matter of great importance to make a comparative study of these

spectra, and to determine whether the same system of classification will apply to spectra obtained by these two widely different methods. Accordingly, a preliminary study has been made of 131 spectrograms, including spectra from Class Od to Class Md.

The Orbits of the Spectroscopic Components of d Bootis.

BY W. E. HARPER.

Fifty-three spectrograms of this F-type star, photographic magnitude 5.3, form the basis of the determination of the elements of the orbit. The plates were obtained mostly with the single-prism instrument but for considerably over half the period of 9.605 days the spectra were separated and measures were made on each component. Elements were determined for each by the method of least-squares, after preliminary elements had been obtained graphically. These were in substantial agreement with each other; but a more rigid determination was effected by combining the observation equations of the two components into *one* set of normal equations thereby deriving uniform values for the elements.

The Variability of Polaris.

BY EDWARD S. KING.

The variability of Polaris having been announced by Professor E. Hertzsprung, I examined the results of photographing stars out of focus, contained in Nos. 4, 5, and 6 of H. A. 59, to discover what evidences of such changes might be afforded.

The corrections given for the individual plates were used to show changes in Polaris for the different nights. The spectroscopic period, 3.9683 days, was accepted. A separate grouping according to phase was made for each of the three investigations. The light curves derived from these three independent series of observations are all of practically the same form and amplitude as Hertzsprung's and confirm his discovery. The curve derived from Nos. 5 and 6 of H. A. 59 suggested a sine curve. Accordingly, such curve was found to represent the ten points given by the grouping. A sine curve having an amplitude of 0.108 magn. is a very close approximation. The residuals, expressed in thousandths of a magnitude, for the ten points are $+6$, $+2$, -9, $+6$, $+8$, -4, -6, $+5$, -7, and $+3$. The average deviation is ± 0.0056.

The effect of the variability of Polaris on the magnitudes already determined by the out-of-focus method was practically eliminated by the nature of the reduction employed in the original work. Corrections were made which included any variation in the light of Polaris; or any change in the conditions occurring between photographing Polaris and the stars observed. The effect was the same as if Polaris had been known to be variable.

No special plates or measures, have been made to obtain the above results All the material has been derived from matter already in type.

The Earth's Radiation Zones.

BY W. J. HUMPHREYS.

Since heat may be transferred from one object to another only by conduction, convection or radiation, therefore by measuring the temperature of the isothermal region of the atmosphere, in which both conduction and convection are small, it is possible to determine the radiation intensity of the earth at as many places as one may wish.

The effective radiating level, as determined by Abbot and Fowle, has an average elevation of about four kilometers, consequently the lower clouds are within the radiating surface while the cirri are above it. Hence the latter and they alone can strongly affect the intensity of the outgoing radiation.

An extensive exploration of the upper atmosphere with sounding balloons has shown that, probably because of the unequal distribution of cirri, the intensity of the earth's escaping radiation within the tropics is to that of latitudes 35° to 60° approximately as 3 to 4. In fact as a radiator the earth has an inefficient equatorial zone, efficient zones of middle latitudes, and finally, for which there is some evidence, inefficient polar caps.

THE AMOUNT AND VERTICAL DISTRIBUTION OF WATER VAPOR ON CLEAR DAYS

BY W. J. HUMPHREYS.

It is important to any one using a bolometer, or a pyrheliometer, to know the approximate amount of water vapor through which the radiation reaching his instrument has passed. In attempting to determine this amount the records have been brought together of 74 balloon flights, made on cloudless days, or such as were adapted to the ordinary use of the bolometer.

According to these data the amount of water vapor per unit volume decreases with elevation on *cloudless* days in an approximate geometric ratio, and the thickness of the water layer that would result from a condensation of all the water vapor in the atmosphere on such days above any given level may be approximately expressed by the equation

$$d = 2\,e$$

in which d is the depth of the water layer in millimeters, and e the partial pressure of the water vapor, at the place of observation, in millimeters of mercury. This value is about 13 per cent less than that given by Hann for all sorts of days, and heretofore commonly used in bolometric work.

On the Masses of Spectroscopic Double Stars.—In *A.N.* 4520 Mr. H. Ludendorff gives some interesting results of a study of 69 spectroscopic binaries with reference to their masses as compared with the sun. He finds from the averages of twenty-five B-type stars and twenty-six of the types A-K that the masses of the former are three times as great as those of the latter.

Again, taking averages, the mass of the principal component varies very greatly with the ratio of its mass to the secondary component. Where the two components are equal their masses do not vary greatly from that of the sun, but where they are very unequal the mass of the larger component is many times the mass of the sun. This is shown in the following table, in which m_1 and m_2 are the masses of the components and α is the ratio of m_2 to m_1.

		Stars of Class B			Stars of Classes A to K		
α	$\frac{(1+\alpha)_2}{\alpha_3}$	m_1	m_2	m_1+m_2	m_1	m_2	m_1+m_2
0.1	1210	544	54	598	181	18	199
0.2	180	81	16	97	27	5	32
0.3	63	28	8	36	9	3	12
0.4	31	14	6	20	4.6	1.8	6.4
0.5	18	8	4	12	2.7	1.4	4.1
0.6	11.8	5.3	3.2	8.5	1.8	1.1	2.9
0.7	8.4	3.8	2.7	6.5	1.3	0.9	2.2
0.8	6.3	2.8	2.2	5.0	0.9	0.7	1.6
0.9	5.0	2.3	2.1	4.4	0.8	0.7	1.5
1.0	4.0	1.8	1.8	3.6	0.6	0.6	1.2

A New Astronomy.—The Governments, Scientific Societies, and Universities of New Zealand and Australia have combined together to send Professor Bickerton to Europe to explain his researches, and "*Knowledge*" has been fortunate enough to secure a series of articles from Professor Bickerton's pen which will appear under the title of "A New Astronomy." The first of these appears in the September issue and deals with the story of Nova Persei of which Professor Bickerton speaks as follows:—

"As the twentieth century dawned an astronomical event occurred that had not had its equal in the history of a celestial observation for some three hundred years. A brilliant temporary star suddenly blazed out in the Northern Hemisphere, and as these evanescent flashes are called Novae, or New Stars, this star was called the New Star of the New Century, and because it was in the constellation of Perseus, it was called Nova Persei.

"Nothing in the whole realm of Nature is so wonderful as this event, the bursting out of a giant sun, its then increasing with amazing rapidity, until it is sometimes many scores of thousands of times the brilliancy of the magnificent luminary that keeps the earth in its orbit.

"And no other celestial event has so fascinated the minds of men, and drawn them to study the heavens as these exploding suns. It is commonly thought that the star of Bethlehem was one of them. Briefly put, Professor Bickerton's theory is that these new stars are made up by the coalesence of the parts which are torn off by two passing suns, when they collide in space, and in the article under consideration Professor Bickerton brings forward the evidence which he has collected in support of his contentions."

The Sun, by Charles G. Abbot, Director Smithsonian Astrophysical Observatory, published by D. Appleton and Co. Price $2.50. It is now thirty years since Professor Young's "The Sun" was first issued and several years since the last revised edition was printed. The last fifteen years have seen great advances made in the study of our luminary through the publication of Rowland's great table of solar spectrum wave lengths, the establishment of the Yerkes, Kodaikanal, Mount Wilson and other observatories largely devoted to solar researches, and the organization of the International Solar Union. The time was ripe for collecting the splendid array of new solar knowledge and Mr. Abbot's close association with the observers at Mt. Wilson, and his own excellent work at the Smithsonian Astrophysical Observatory, under and succeeding Langley, have fitted him especially for carrying out this important task. The book is brought thoroughly up to date and contains many results of observations which have not yet been published. Chapter VI entitled" What is the Sun?" gives the latest theories of the constitution of the Sun. Later chapters treat of the sun as the earth's Source of Heat, the Sun's Influence on Plant Life, Utilizing Solar energy, The Sun among the stars. The book is well illustrated, including some of the most perfect photographs of nebulæ recently obtained by Professor Ritchey at Mt. Wilson. Two very valuable plates, not published elsewhere so far as the reviewer is aware, give reproductions of typical stellar spectra, of the types B_2, A, F_5, G, K, M_a and M_d, with Titanium comparison spectra, from photographs taken with the Mills spectrograph of the Lick Observatory. The book is written in comparatively simple language and may be read with interest by those having but little knowledge of the technical terms of astronomy and physics.